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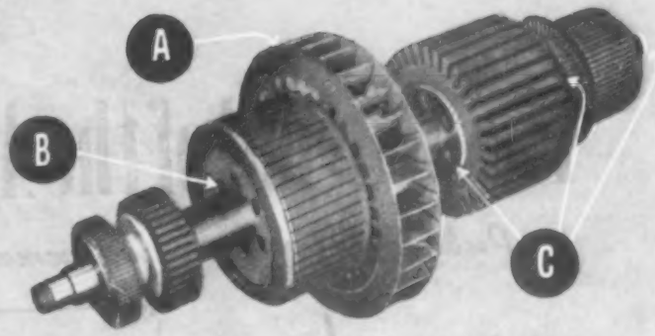

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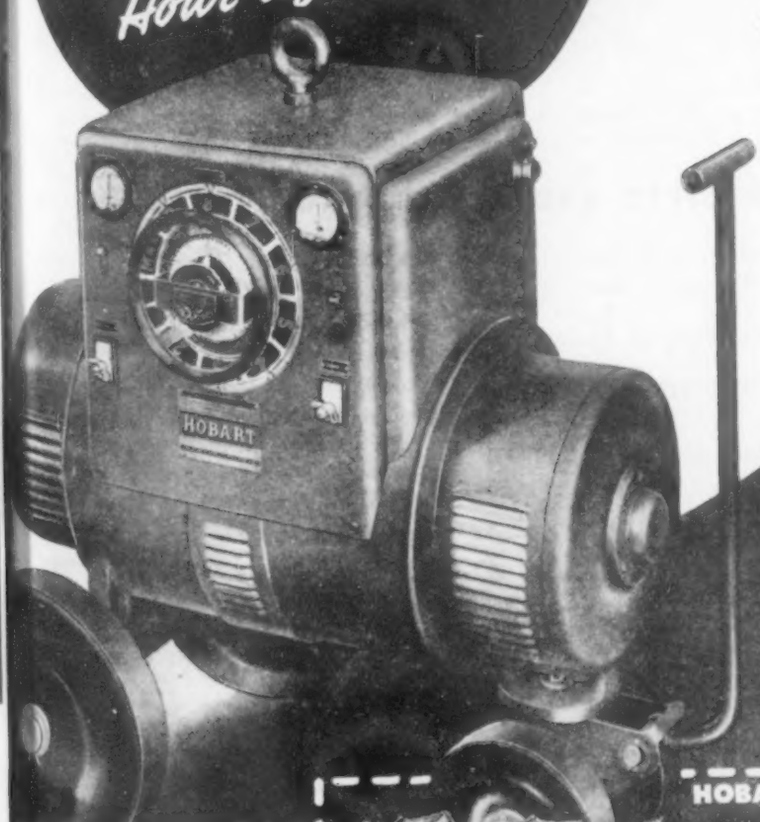

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The Journal of the American Welding Society

Published for the Advancement of the Science and Art of Welding

W. SPRARAGEN, Editor

OCTOBER, 1945

VOLUME 24 NUMBER 10

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Examination of Welded Joints by Trepanning with Special Application to Shipbuilding*

By J. B. Arthur† and M. H. MacKusick‡

IN ORDER to be reasonably sure of the soundness and quality of welded joints on a ship, visual inspection is not enough. Therefore, some method must be used which will tell of the condition inside the joint.

Several standard methods are available. However, each has its limitations, advantages and disadvantages. The selection of the best method to be used depends on the information required and the use of such information.

At Calship we desired the following information at a minimum cost, in the shortest possible length of time:

1. Soundness of the weld, i.e., absence of defects such as slag, gas pockets, lack of fusion, cracks, lack of penetration, etc.
2. Plate edge preparation for welding.
3. Fit-up of the two members prior to welding.
4. Procedure of welding, i.e., weave or stringer beads, type and size of electrode, etc.
5. Examination of the plate stock for segregations and laminations.

We then desired to use this information in the following ways:

1. To serve as an inspection control of welding and fitting quality in certain joints.
2. To analyze welding practices and procedures.
3. To serve as an educational and informational medium for the operator as well as for supervision and management.
4. To serve as a permanent record of the welding of each unit and hull, so that comparison could be made of supervision, welding operators, procedures, and also to locate common difficulties on specific joints.
5. In case of defects, to use for the determination and fixing of craft responsibility (fitters, burners, chippers, welding operators, etc.).

Some methods which could be used and the comparison of such methods are shown below:

Method	Advantages	Disadvantages
X-Ray	1. Non-destructive. 2. Locates most defects in one shot 3. Covers considerable linear length of joint (6–18 in.) 4. Indications are photographed, making a permanent record.	1. Requires considerable equipment which is not too portable. 2. Certain types of defects are not revealed. 3. Photograph difficult to positively interpret, even by experienced personnel. 4. Skilled personnel required to handle equipment.
Radium (Gamma-Ray)	1. Same as X-ray. More portable than X-ray; however, not as sensitive in some applications.	1. Certain types of defects are not revealed. 2. Photographs difficult to interpret even by experienced personnel. 3. Skilled personnel required.
Trepanning	1. Locates defects. 2. Tells complete story at that one spot with no question, i.e., fit-up, plate condition, preparation, procedure. 3. Photographs are easy to interpret with minimum of explanation to average person.	1. Is destructive. 2. Covers small area
Magnaflux	1. Locates surface or semisurface defects.	1. Cannot tell the complete story.

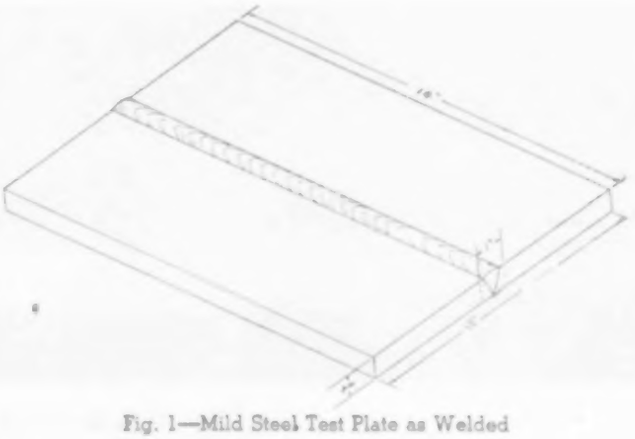


Fig. 1—Mild Steel Test Plate as Welded

* Scheduled for the Twenty-sixth Annual Meeting, A.W.S., October 1945.
† Testing Engineer, Calship.
‡ Welding Engineer, Calship.

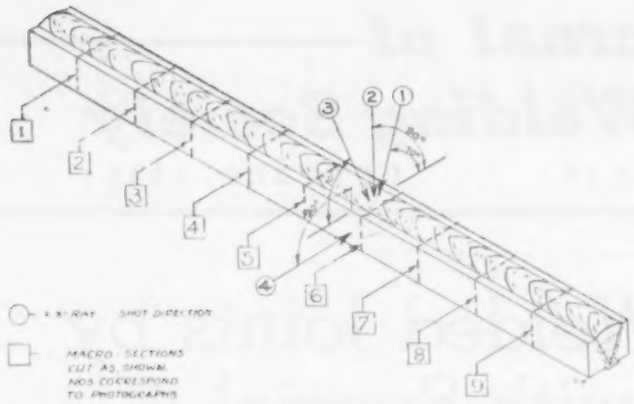


Fig. 2—Weld Slug with Notation on X-ray Sectioning Locations and Directions

2. Nondestructive.	2. No photographic record. 3. Not satisfactory on deep defects.

If the ultimate in perfection of weld quality inspection is required, a combination of the inspection techniques outlined above will be necessary. However, in analyzing these methods we felt that trepanning was more suitable for our use due to the following major considerations:

1. Certain critical types of defects are not detectable except by trepanning.
2. Plate edge preparation, fitting, etc., cannot be suitably and definitely determined after the joint is completed, except through trepanning.
3. Steel stock used cannot be checked for defects such as laminations and segregations by the use of any method other than trepanning.
4. Photographs are easily made of trepanned plugs and serve our purpose ideally. Education of various personnel concerned is unnecessary. An extremely vivid picture of all conditions involved is available. There is no argument as to interpretation.
5. Cost is cheaper in trepanning than in making X-ray or gamma ray shots. A cost survey was made in the yard and then checked elsewhere in heavy industry such as shipbuilding, pressure vessels, etc., and verifies this lower cost. This lower cost covers cost of repair of holes after plug removal.

To very clearly illustrate points 1, 2, 3 and 4 above, a weld containing a serious longitudinal cracking condition was made. The test plate as welded is shown in Fig. 1. This crack was introduced by incorrect sequence and severe restraint of the members while welding. It is a more or less common type of serious defect in heavy construction. A recapitulation of trepanned test plugs removed from 20 Victory ship hulls shows a small percentage of defective welds which required further examination and repairs. Of this small number of defective welds, 30.62% of all such were cracks of more or less serious extent, and it is doubtful that any other means of

Root Face

Fig. 3—Visual Appearance of Weld

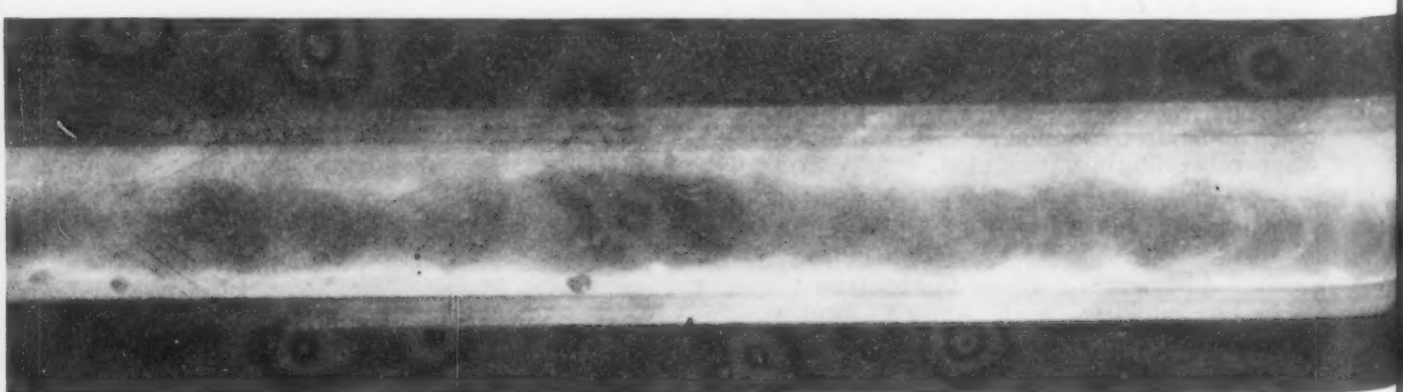


Fig. 4—X-Ray at #2 Direction on Weld Slug

Fig. 5—Etched Section at #4 Location on Weld

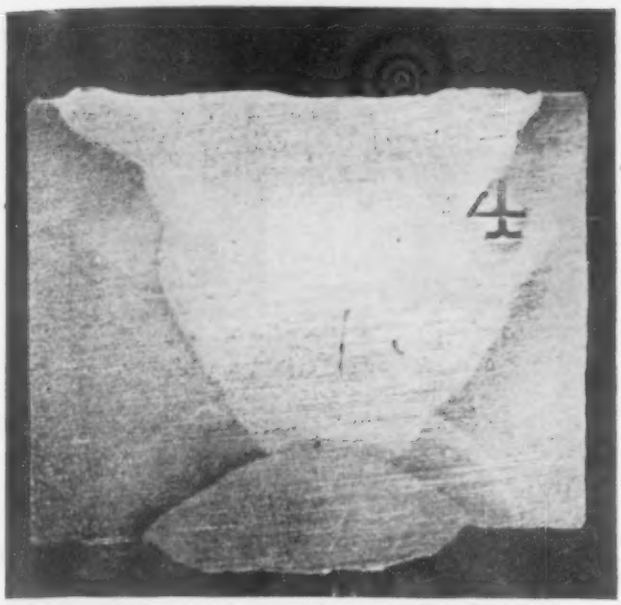


Fig. 6—Etched Section at #7 Location on Weld

examination would have revealed any appreciable number of these defects.

The weld slug containing the cracked weld beads was sawed out as shown, and four X-ray shots taken in the indicated directions as shown in Fig. 2. After magnaflux inspection of the weld, nine sections were then cut from the coupon as shown on the same drawing. They were then polished and etched. All etched sections show cracking. See Figs. 5 and 6.

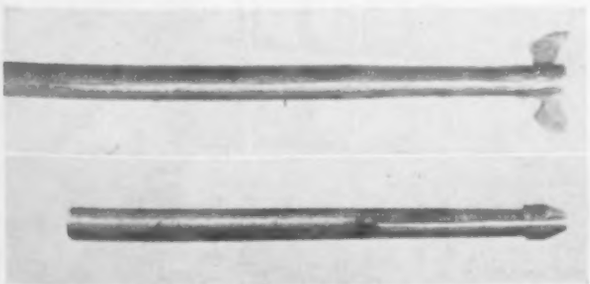


Fig. 8—Special Pilot Rod Used to Prevent Plug Dropping Through Hole at End of Cut

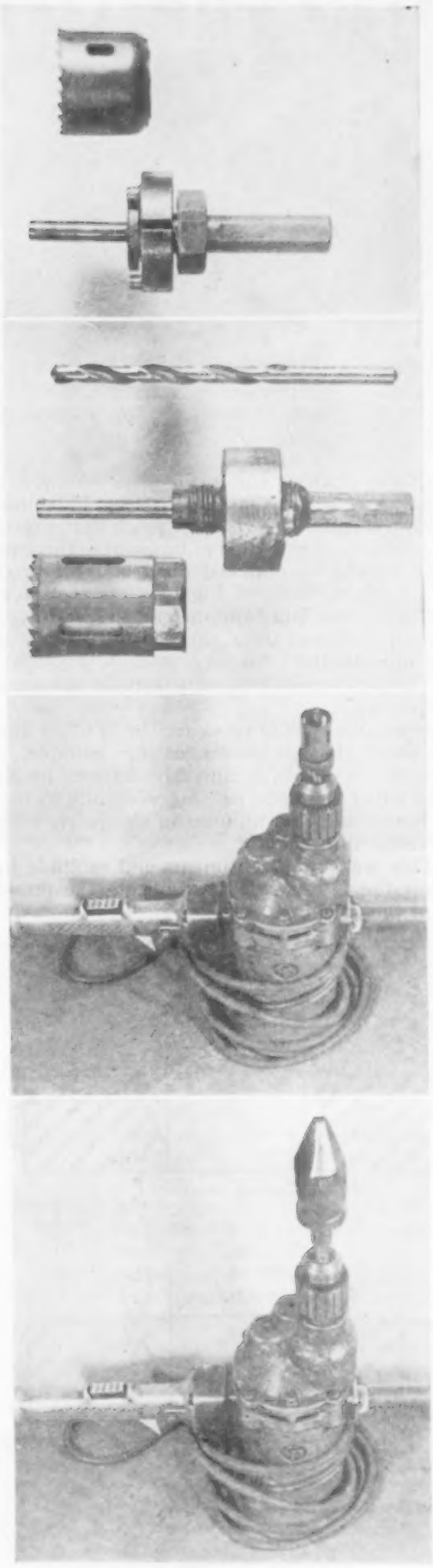


Fig. 7—Tools Used in Trepanning

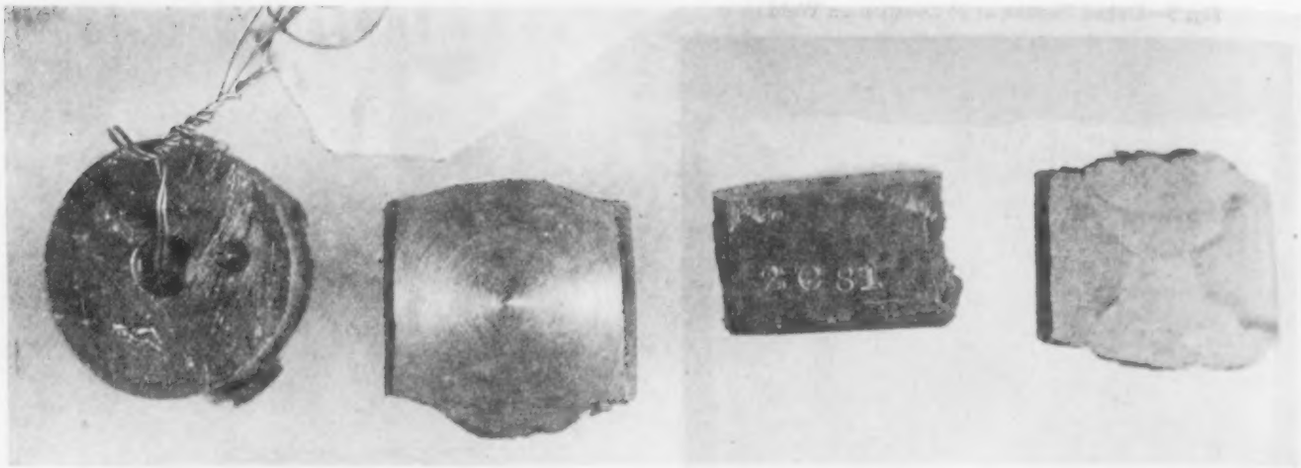


Fig. 9—Preparation of Plugs for Examination

The X-ray pictures were made using film with a much finer grain and better contrast than would be used commercially; therefore, they are of much better quality, so far as determining condition of the weld in this case, than would normally be obtained on a straight production job. The photographs of Figs. 3 to 6, inclusive, show the weld slug, the X-ray and the etched sections.

An examination of these photographs and an analysis thereof indicates the following:

1. This is a serious type of defect and not uncommon in occurrence.
2. Since this type of crack can be in other directions to the X-ray than as shown, as, for example, sulphur cracking in Unionmelt, it cannot be detected by X-ray in any case other than one running vertically in the plane of the beams and also uniform in character, with practically visible dimensions.
3. This crack was continuous and multiple in some cases but the X-ray failed to indicate the presence or extent of the cracking.
4. Magnaflux inspection did not indicate that the weld was defective.
5. The only satisfactory way to determine the presence of this type of defect and the seriousness of such defect is by trepanning.

In order to familiarize others who may be interested in the use of the trepanning method for inspection and control of welding, the following system and procedure as used at Calship, is outlined.

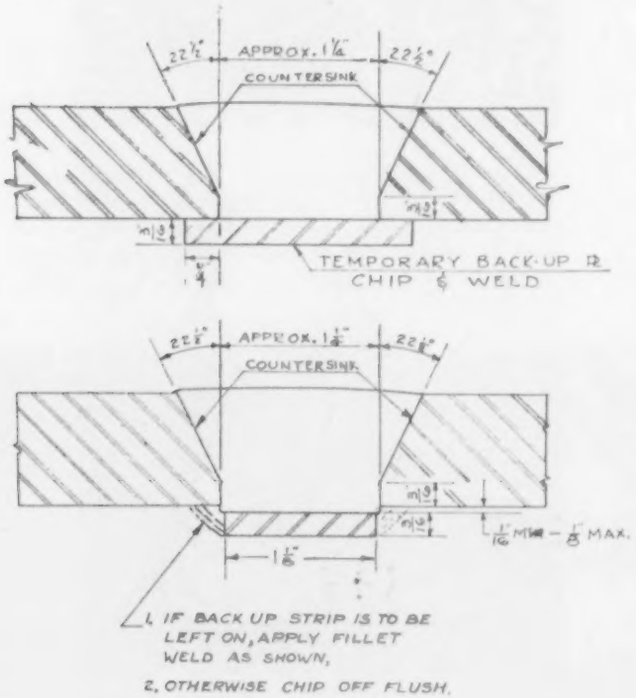
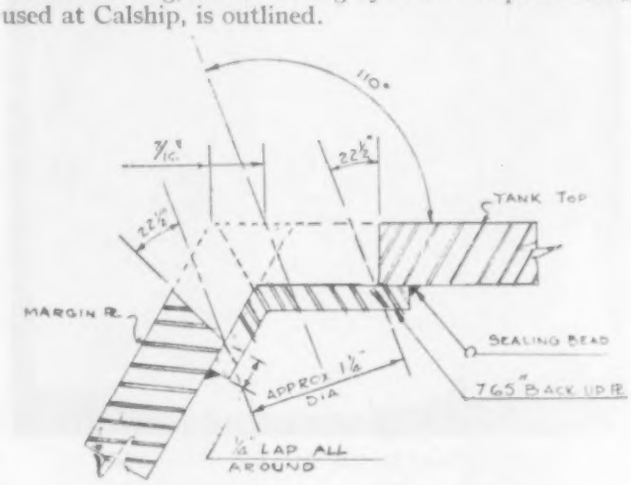


Fig. 10—Repair of Hole Left by Removal of Plug



REPAIR OF TEST PLUG HOLE OF KNUCKLE JOINT SUCH AS SLOPING MARGIN PLATE TO TANK TOP PLATING.

Fig. 11

Fig. 12—Use of Photographs for Education of Personnel

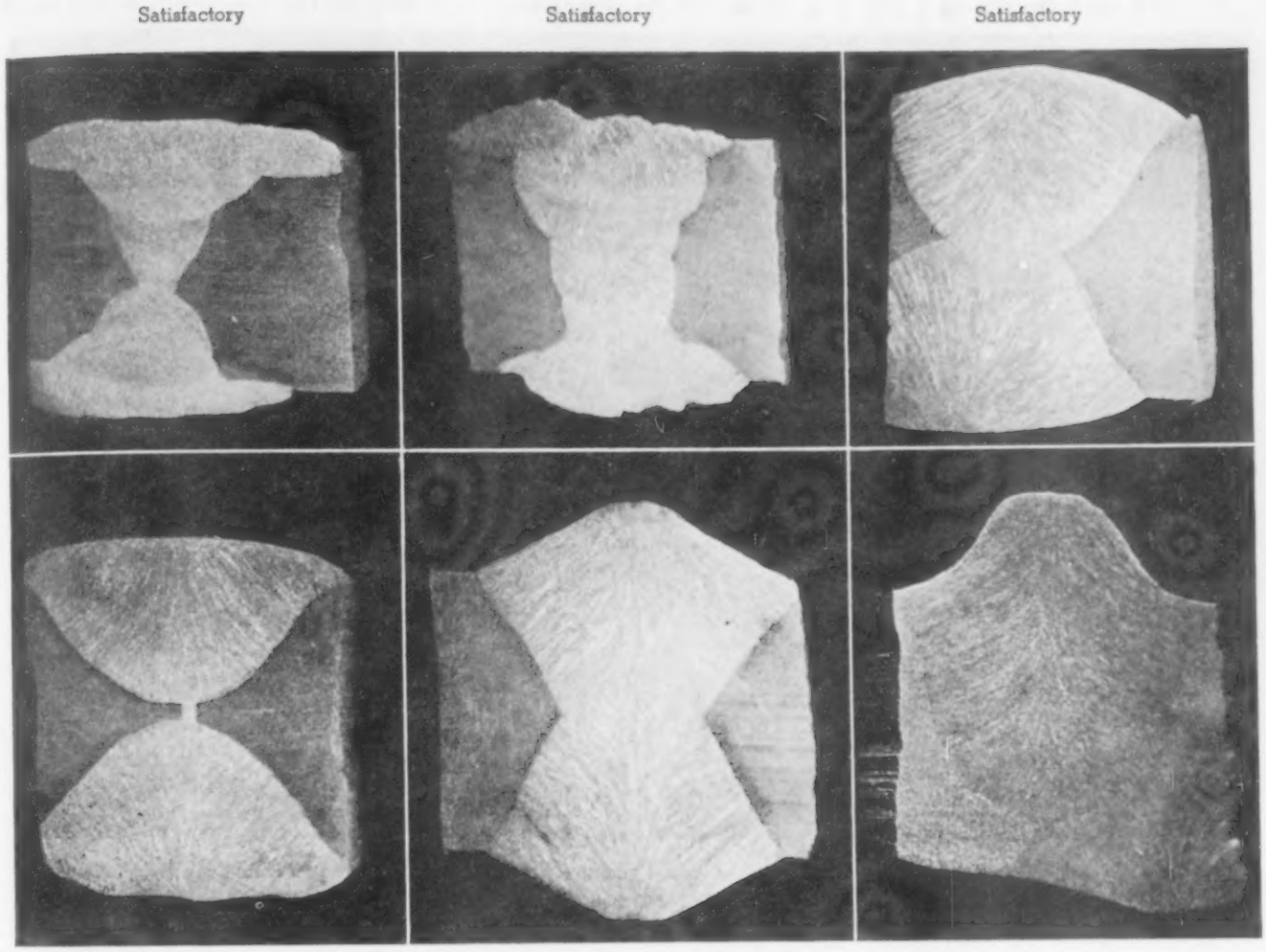


Fig. 13

The locations of test plugs on the various joints were selected by a committee of all interested persons and agencies. These locations cover the following critical spots:

1. Erection butts of subassembled sections—shell and decks.
2. Tank joints.
3. Welded joints at the critical stress points of the ship, including subassembly welded joints in such locations.

The test plugs are marked off daily in line with welding completion of the joints in each unit involved. Test plug crews then take the plugs from the locations as marked. Procedure in actual machining out the plugs, preparation for examination, repairs, etc., is as follows:

1. *Trepanning.*—

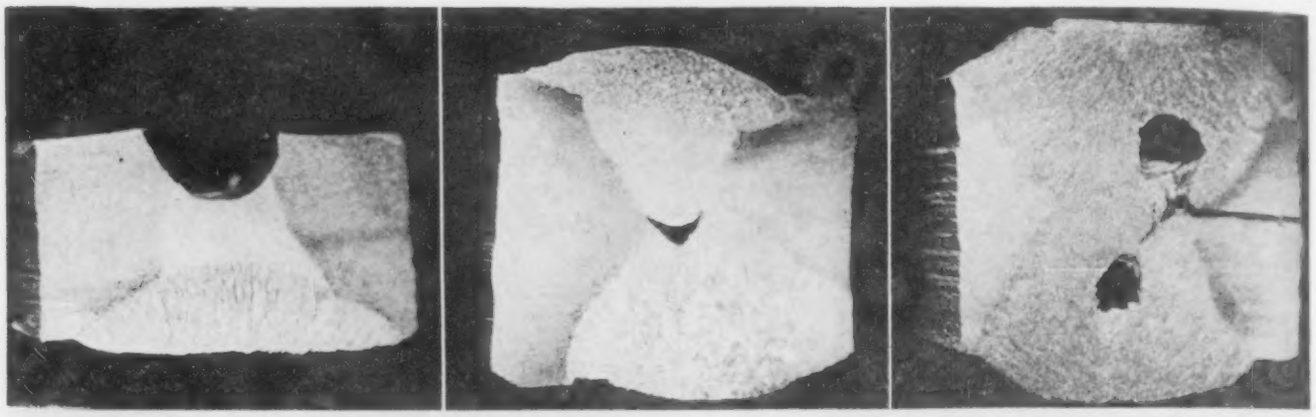
(*a*) Equipment required (see Fig. 7):
(1) "F" size drills.
(2) 1/4-in. electric drill for pilot hole.
(3) 3/4-in. heavy-duty electric drill for saw and countersink.
(4) Arbor.
(5) Hole saw—1 1/4 in. diameter.
(6) 2-in. reamer with 45° taper.
(7) Midget air chipping gun.
(8) Specially tipped chisels.

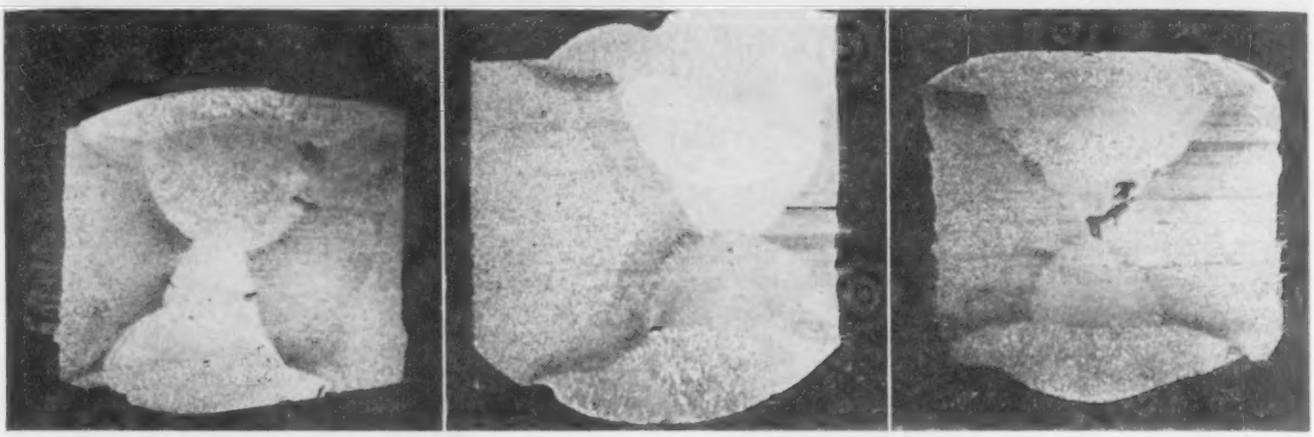
(*b*) Operations:
(1) Drill pilot hole using "F" size drill.
(2) Use special tempered guide in arbor—1/4 in. diameter.
(3) Start sawing with a dull saw to prevent breaking teeth, and groove 1/8 in. deep using guide.
(4) Replace worn saw with sharp one. Remove guide and continue through the material.
(5) A pry bar or "old man" may be used to maintain steady pressure in overhead or horizontal trepanning.
(6) When sawing in a flat position, air can be used to keep cuttings cleaned from around the saw teeth. Cuttings clog saw causing excessive heating and binding. In case a tooth breaks off and becomes clogged in the groove, a chipping tool can be used in a midget chipping gun to dislodge the teeth.
(7) In flat trepanning, the plug, after being removed from the plating sometimes falls out of the saw before the operators get it. To overcome this difficulty a tool as shown in Fig. 8 was devised to serve as a continuous guide until the operation is complete. The clips fly out under centrifugal action. It can be seen that

Correct Back Chipping

Chipping Chisel Too Narrow

Laminated Plate Contributing to Weld Porosity





Checks Due to Plate Segregation

Laminated Plate One Side of Plug Only

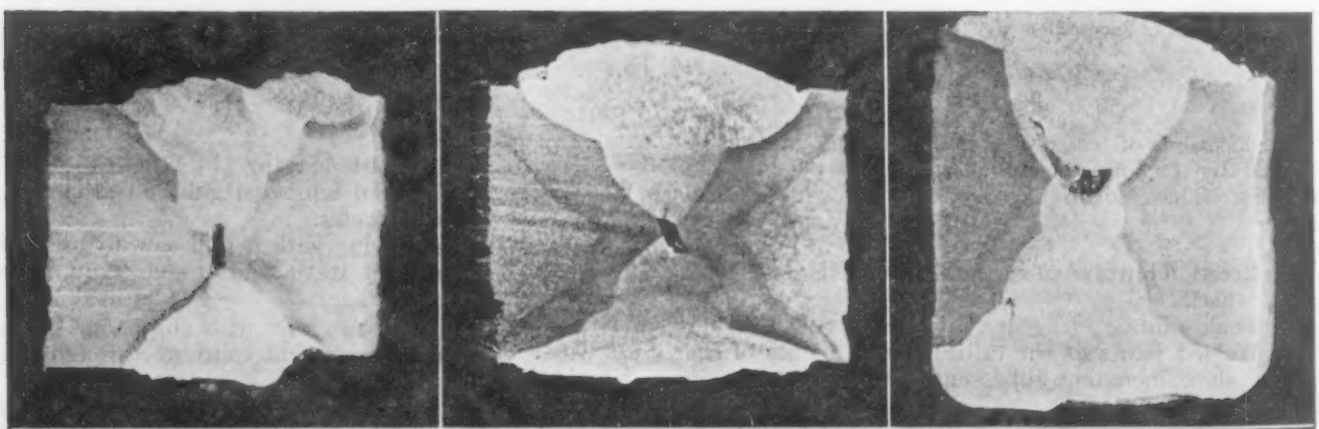
Incorrect Plate Edge Preparation

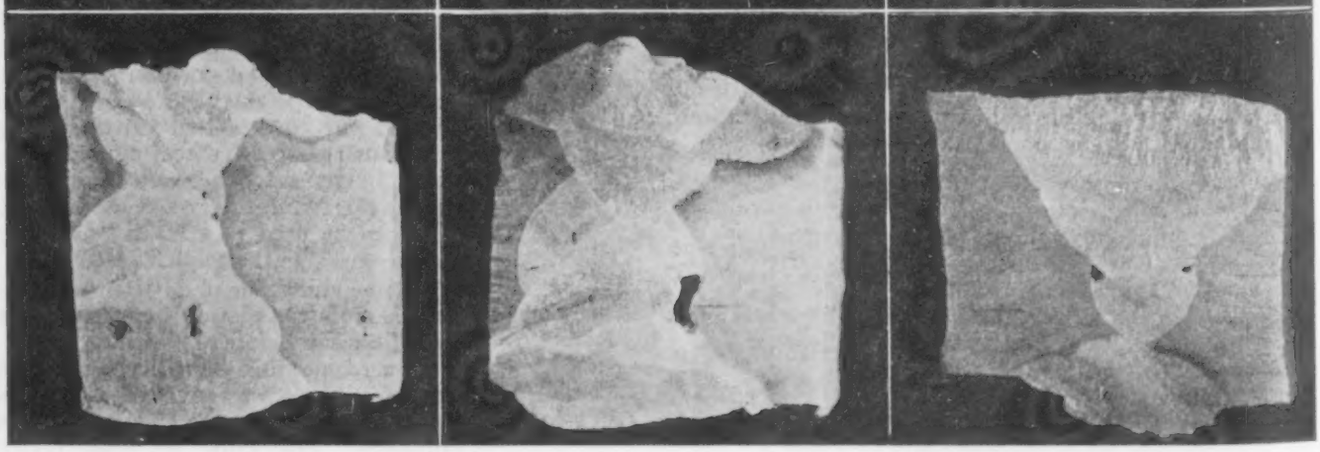
Fig. 14

Excessive Land with Tight Fit

Not Enough Root Opening

Slag Inclusion





Slag and Gas Pockets

Void Due to Faulty Second Pass Welding

Slag Inclusion Due to Undercutting Both Bevels on 1st Pass with Consequent "Trap" Not Fused Out

Fig. 15

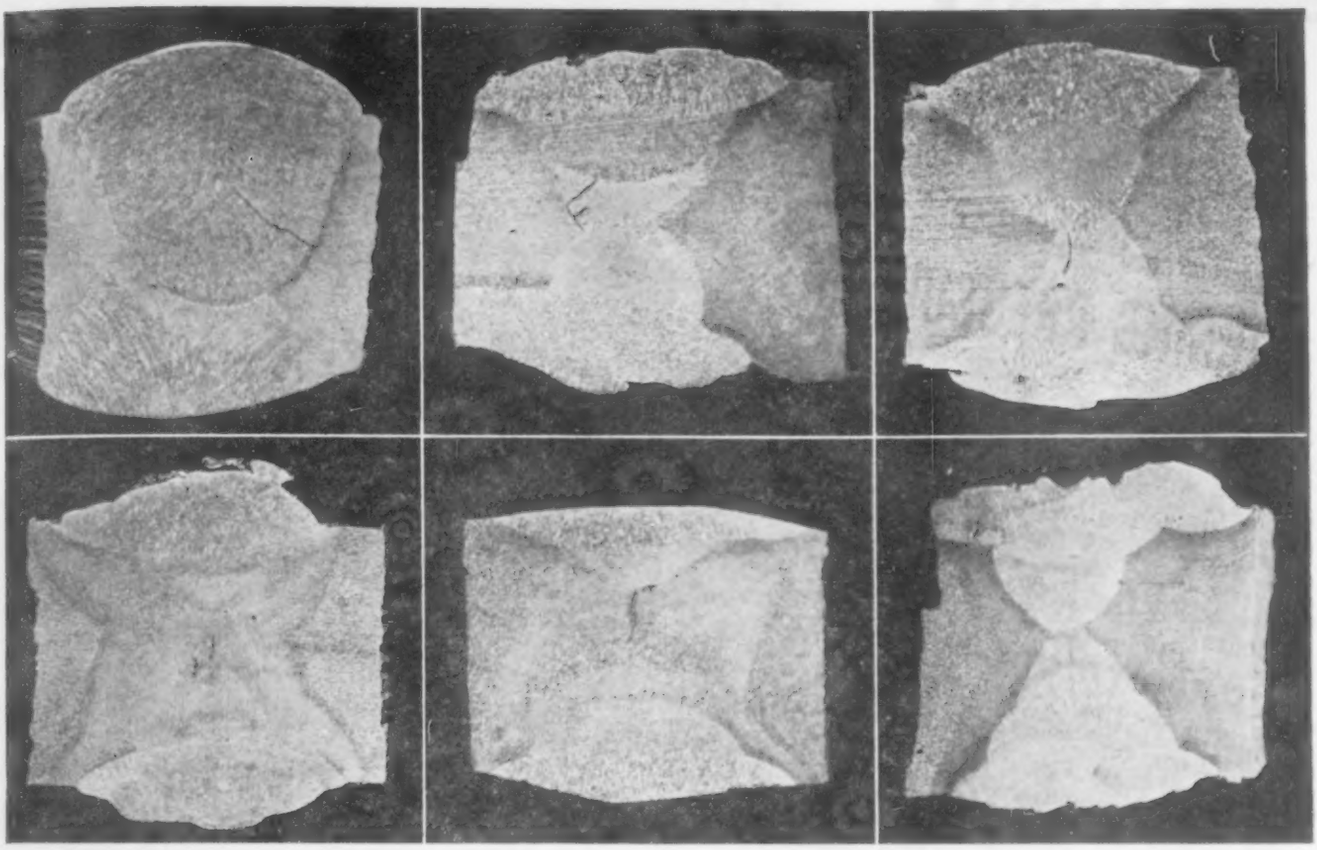


Fig. 16—Examples of Weld Cracking

the plug will fall against the "butterfly" and will not drop out into the compartment below. Another type is the slotted "spring" type also shown. The butterfly type is more satisfactory.

(8) To facilitate repairs, after removal of the plug, the hole is countersunk using a 2-in. reamer with a 45° taper countersinking to within $^3/_{16}$ in. of bottom of the hole, thus leaving a $^3/_{16}$-in. land.

2. Preparation of Plug for Examination.—Figure 9 shows the plug in various stages of preparation. On the left side the plug is shown as tagged and as received from the ship. Second from the left is the plug as faced down in the lathe. Third from the left shows stencil identification on the edge. And the picture on the right shows the plug as polished down and etched. The procedure for examination preparation is as follows:

(*a*) Face down the plug in a lathe in a direction perpendicular to the line of a weld.
(*b*) Stencil identification on edge of plug.
(*c*) Polish plug on a water belt sander.
(*d*) Etch with iodine solution and then with ammonium persulphate solution.
(*e*) After taking photograph of both sides at $2^1/_2$ magnification, cover etch with glyptol for preservation.

3. Repair of Plug Holes and Defective Welding.—A record of examination and decision as to the condition of the weld is made on a test plug record card. If the weld must be repaired, then the seam is ripped open with a scarfing torch or by chipping, but preferably by the torch since defects appear and can be washed out much more readily by this method (also being much cheaper), and it is rewelded. If defects are minor or are not present, then the hole is repaired as shown in Figs. 10 and 11.

4. Complete Reports by Hulls are then made up and sent to all interested personnel and agencies. In the meantime, however, pictures are given to production supervision and personnel for education of welding operators and for use in correcting fitting, chipping, burning, etc. These photographs are posted as shown in picture in Fig. 12, in the offices on the shipways, skids, etc. In other words, to obtain effective use of test plugs, it is necessary to follow through at the earliest possible time.

In order to analyze defects and to know the relative seriousness of each one, it is necessary to have a set of standards. Since information concerning standards is scarce on this type of inspection, we felt it necessary to make numerous physical tests on welds containing known types of defects. The number of tests so made is approximately 5000 at the present time. Through the results of these tests we arrived at our set of standards.

Corrective remedies were also set up at the same time in order to prevent, as far as possible, the occurrence of these defects on production welding. Typical welds with a notation as to the interpretation of the macrograph are shown in Figs. 13, 14 and 15, inclusive. Figure 16 shows serious cracking defects of various types in welds. It is highly doubtful if these cracks could be detected by any method other than trepanning.

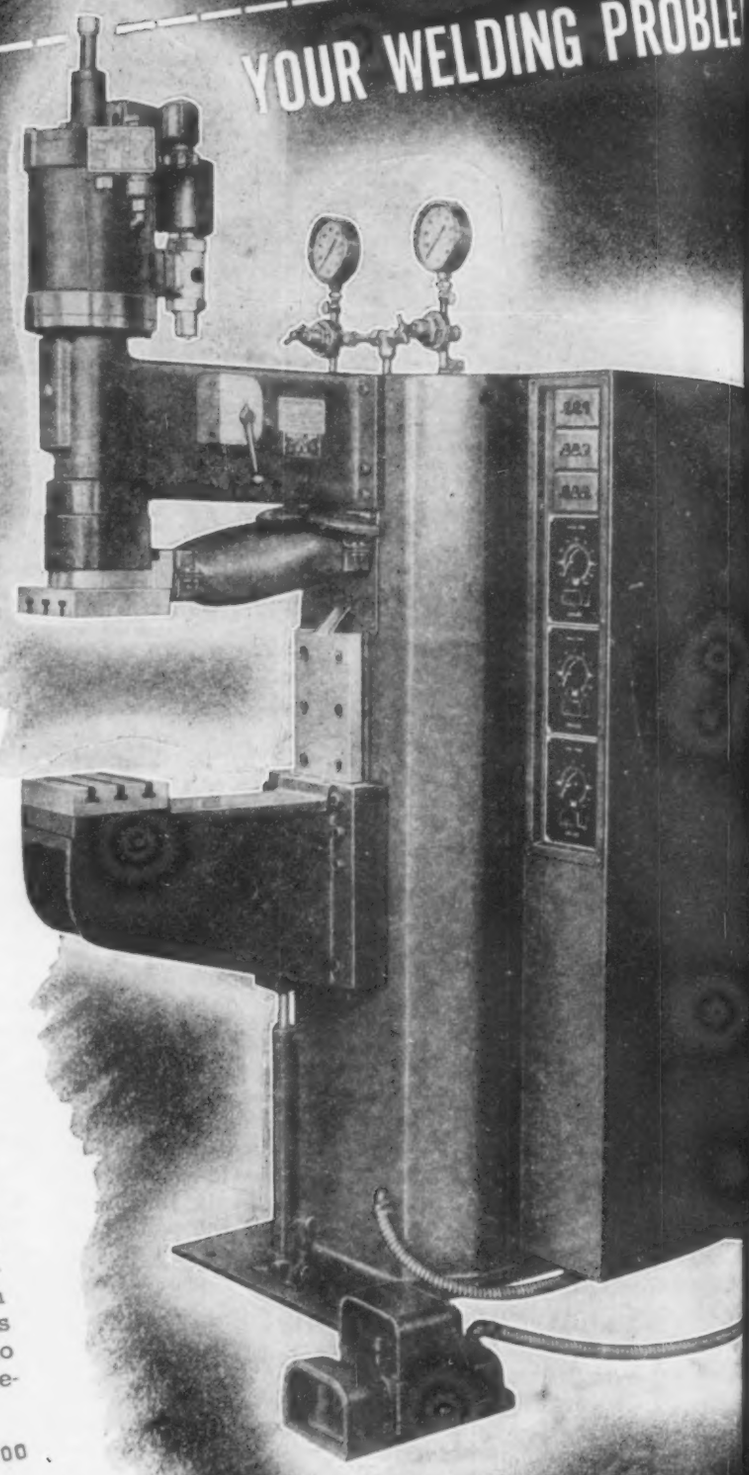
In conclusion it would appear that the ideal inspection procedure would be a combination of trepanning and X-ray procedure. We also wish to recommend that the various societies—the A.S.T.M., the A.W.S., the A.S.M.E., etc.—draw up a standard welding inspection specification for trepanning. We believe that there is a definite need for such a specification, and that it would tend to complete the set of standards of inspection now available.

Trepanning is a valuable tool. It has its place in welding inspection.

SCIAKY

4915 WEST 67TH STREET
CHICAGO 38, ILLINOIS

SE FORGING PRESSURE IN YOUR WELDING PROBLE



rating:

150 KVA at 50% duty cycle. Single phase alternating current of one voltage and one frequency. Power supply may be 440 or 220 volts, 60, 50 or 25 cycles, according to the user's specifications.

performance:

CAPACITY: As a projection welder—6 projections on .080" plus .080"—distance between welds ¾"; projections in accordance with RWMA standards. Maximum current on secondary side, 31,000 amps. with a distance of 11½" between arms. As a spot welder—(electrode holders optional equipment) stainless or clean mild steel from .032" plus .032" up to and including .187" plus .187".

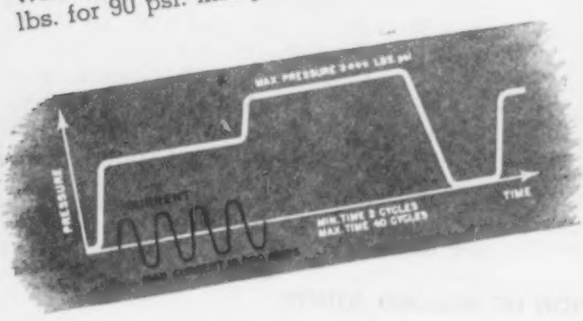
SPEED: 180 welds per minute on .032" plus .032" pickled mild steel.

THROAT DEPTH: 18" from center line of welding ram to face plate.

CLEARANCE BETWEEN ARMS: Lower arm adjustable over a range of 11½". Maximum working space between arms 21".

ELECTRODE STROKE: Adjustable stroke, retractible head, permits a working stroke of ½" with foot controlled retraction to give a total opening up to 2¾". Selection of constant working stroke, or working stroke with retraction is through toggle switch mounted on control panel. The retraction feature is designed for spotwelding. It may also be used for projection welding if desired.

WELDING PRESSURE: Maximum 3000 lbs. for 90 psi. line pressure.



PMC01-9
projection welder

LETIN 120-A

The Heliarc Welding Process as Applied in the Aircraft Industry[†]

By Thomas E. Piper[†]

THE welding processes in the aircraft industry are the most important and most commonly used processes for the joining of metals; therefore the closest control must be maintained for uniformity in production to assure that the high allowable design factors used by the Aeronautical Engineers are maintained.

In order to illustrate the important part welding plays in the fabrication of airplanes we have only to note its application on one of the Army Air Forces most popular pursuit planes.

The engines are attached to the fuselage by metallic- and gas welding. The steel spar caps that connect the wings and support the crew nacelle are jointed by flash welding. The Empennage or tail structure is supported by spot-welded aluminum alloy booms. The wing tips, nose-cradle, instrument panel, spoilers, pully brackets, hydraulic reservoir and many other small parts made of magnesium and aluminum alloys as well as stainless steel collector rings and exhaust stacks are fabricated by Heliarc welding.

Necessity was the mother of Heliarc welding of magnesium. The earth's most abundant metal had been developed to the point where it could be launched on an important career in industry. However, no material can have a great career without the aid of a good method of joining.

* Scheduled for the Twenty-Sixth Annual Meeting, A.W.S., October 1945. Also presented before the San Francisco Section, A.W.S., April 23, 1945.

† Northrop Aircraft, Inc.

Fig. 1—Heliarc Welding

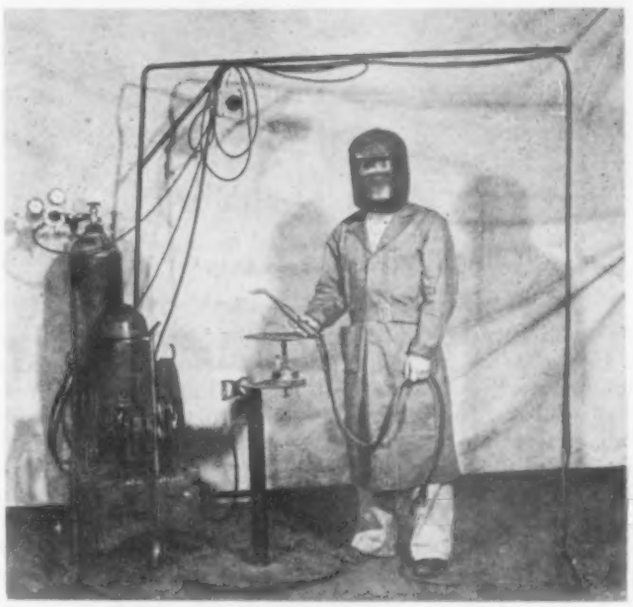


Fig. 2—Heliarc Welding Equipment

In November 1939, John K. Northrop, President and Director of Engineering of Northrop Aircraft, Inc., with his characteristic foresight into the future of aircraft design, saw the possibility of magnesium as a material for aircraft construction when designed where fatigue strength, resilience, dampening capacity, toughness, stiffness and weight characteristic could be attained. Realizing that a successful method of jointing was the requisite to the success of adapting the material to aircraft, he conceived and instigated the development of monatomic inert gas-shielded arc welding and with the cooperative efforts of engineers, technicians and shop personnel, the Northrop Group has produced a welding process which opens the door to unlimited development in the fabrication of stainless steel, magnesium, aluminum and copper alloys, low-carbon and alloy steels for aircraft and industrial applications.

Culminating research over a two-year period, Northrop Aircraft, Inc., perfected the Heliarc welding process. An important part of this process is the Heliarc torch which consists simply of a tungsten electrode shielded from the atmosphere by an inert gas flowing from one or more orifices in the torch. This inert gas prevents the formation of oxides in the molten weld metal thus eliminating the necessity of using a flux. The inert gas further eliminates the accumulation of heat around the weld, thereby allowing better fusion and penetration and less distortion than is possible with ordinary arc or gas welding. (See Fig. 1)

Standard arc-welding equipment may be used for this process, consisting of a d.-c. motor generator set, a pair

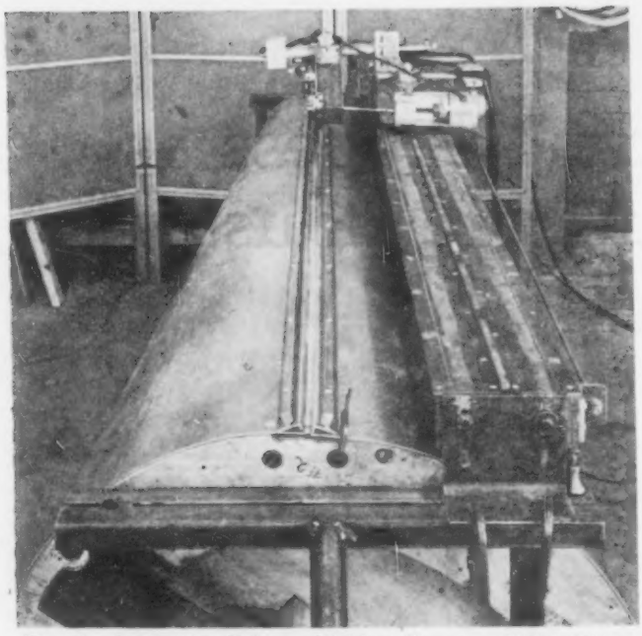


Fig. 3—Automatic Heliarc Welder Showing Weld When Completed. Welding Speed 12 In. per Minute

of flexible cables, a tank of monatomic gas such as Argon or Helium, two-stage pressure regulator with flowmeter, Heliarc torch and an operator's welding helmet. Practically all d-c. welding type generators are suitable for Heliarc welding but they must have a current capacity ranging for light work up to 150 amp. and for heavy work up to 300 amp. Although Heliarc welding requires a distinct procedure and technique, the skill required for learning and operating is no greater than that of gas or arc welding. The welding rod selected should be of the same approximate composition as the material being welded. See Fig. 2.

A new development having considerable merit is the use of high frequency current* superimposed on the welding current. It has been found by the use of high frequency that the heliarc welding of stainless steel,

* "Missing Link" manufd. by Mid-States Equipment Co., 2429 S. Michigan Ave., Chicago, Ill.

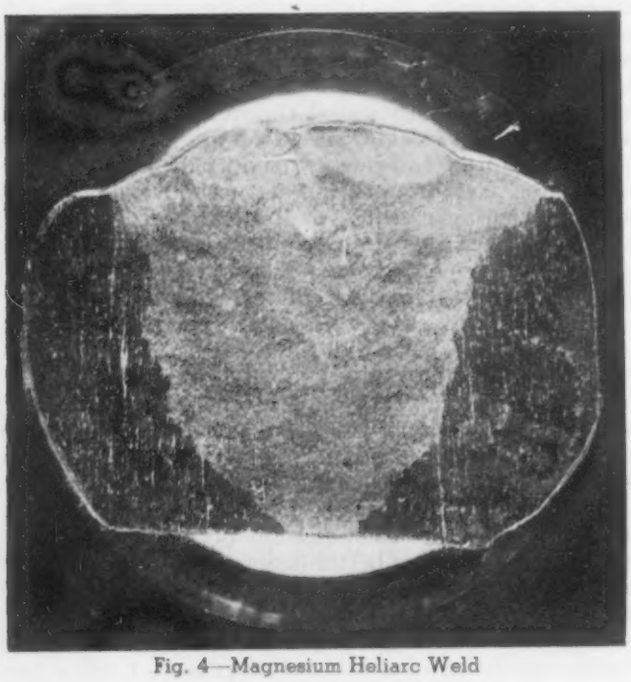


Fig. 4—Magnesium Heliarc Weld

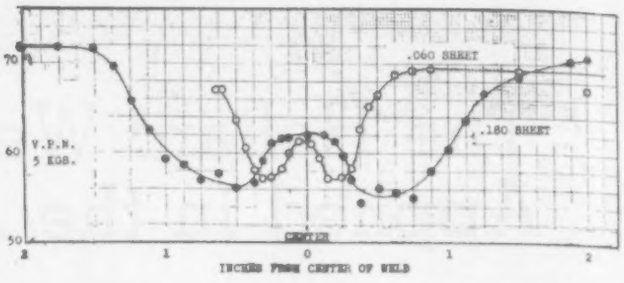


Fig. 5—Hardness Survey of Heliarc Welds in Magnesium Sheets

aluminum, magnesium and other nonferrous and ferrous alloys is greatly improved. By means of high frequency, not only is the Heliarc operator able to eliminate striking the arc, but a more stable arc is obtained, resulting in high quality and smooth-appearing welds.

Although our original work was done using helium as the blanketing gas, we have found that argon gas is equally as satisfactory. Argon composes 0.95 of 1% of the earth's atmosphere and is therefore readily available in inexhaustible quantities.

All types of joints as commonly used by comparable welding method may be designed to manual Heliarc welding except aluminum alloys where fillet welds are not yet possible.

When design permits, the machine Heliarc weld method is recommended. This consists of a variable controlled rod feed with Heliarc torch mounted on a travel carriage that will uniformly deposit a bead at a speed of 36 in. per minute. See Fig. 3.

Heliarc butt weld joints in J-1H or AMC57SH magnesium alloys possess an average of 95% of the strength of base material and design-allowable strength of 75% of that of the base metal if used for primary structures. The reduction of distortion allows production of the

Fig. 6—Inside and Outside View of Automatic Heliarc-Welded Magnesium Boom

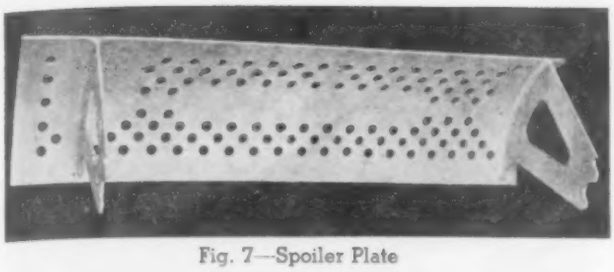


Fig. 7—Spoiler Plate

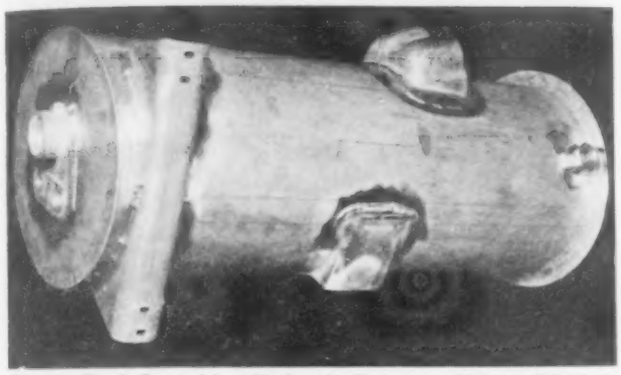


Fig. 8—Tank Assembly—Hydraulic Reservoir, Heliarc-Welded Magnesium

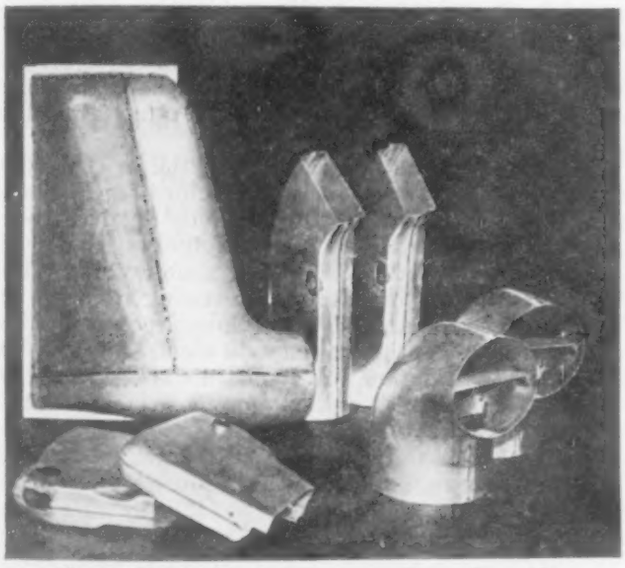


Fig. 9—Heliarc-Welded Aluminum Direct Assembly

smooth parts required in aircraft and a faster production rate. The weakest area of a Heliarc-welded joint is in the heat-affected zone adjacent to the weld bead as is commoni n most other welding processes when parts are not heat treated after welding. See Figs. 4 and 5.

The standard fatigue limit of 0.060 J-1H magnesium unwelded sheet is 12,000 psi., while the fatigue limit for the Heliarc butt-welded joint is 0.060-in. J-1H magnesium sheet alloy is 11,000 psi. The fatigue limit of 0.180-in. J-1H unwelded magnesium sheet is 13,000 psi. as compared to the fatigue limit for a Heliarc butt weld joint in 0.180-in. J-1H magnesium sheet of 11,000 psi. All fatigue limits are based on 100,000,000 cycles of stress without failure.

Good penetration and freedom from oxide inclusions, presenting a sound, dense grain structure, are characteristics of the Heliarc magnesium weld bead.

The demand for implements of war has greatly increased the production facilities for light alloys which will promote a greater use of light alloys for postwar industrial applications, and it must be acknowledged that with the production facilities now available, postwar will see us in the age of light alloys.

The production of magnesium in 1941 was approximately 20,000 tons per year and increased in 1943 to 200,000 tons per year, while that of aluminum alloy was 300,000 tons per year in 1941 and increased to approximately one million tons per year in 1943.

In the Heliarc welding of aluminum alloys, the tungsten electrode and a welding rod of approximately the same material as the base metal is required. A light coat of flux applied to the weld surface is necessary to inhibit oxidation of the weld bead. A standard d.-c. motor generator with a high frequency superimposed on the d.-c. current is recommended to promote a stable arc and make smooth standard welds on aluminum without difficulty. See Figs. 6 to 8.

The greatest advantage of Heliarc welding aluminum alloys is the benefit derived by using a welding rod composed of approximately the same alloy as the parent material or by using a flange butt weld method, whereas in the conventional methods of welding aluminum a 5% silicon rod is used which gives lower ductility and lower mechanical properties to the weld bead. Only butt and flanged joints, edge and corner welds are permissible, fillet welds are not practicable. See Fig. 9. Flanged melt down joints with no filler rod is recommended for volume production.

By extensive laboratory test it has been proved that the ultimate physical strengths of gas and Heliarc welds in aluminum alloys are comparable and there is a definite

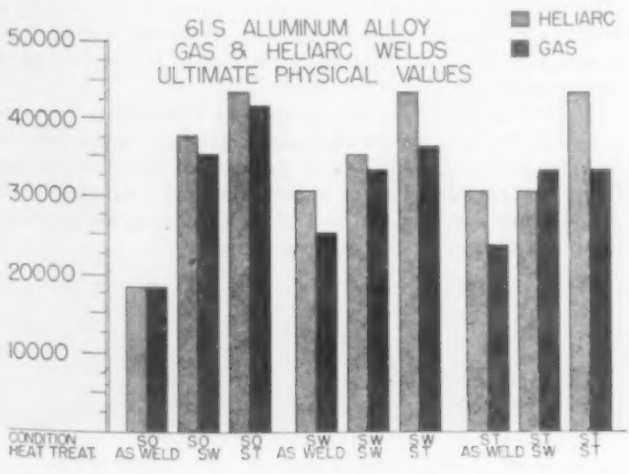


Fig. 10

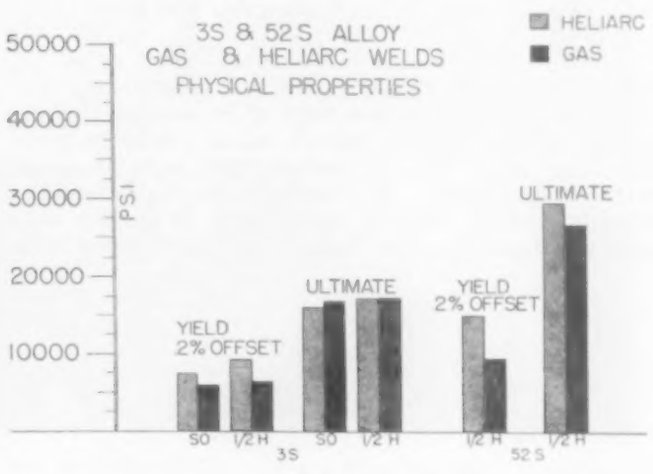
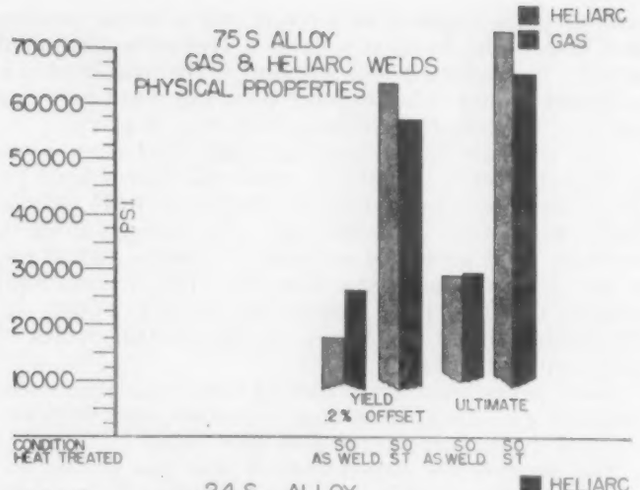
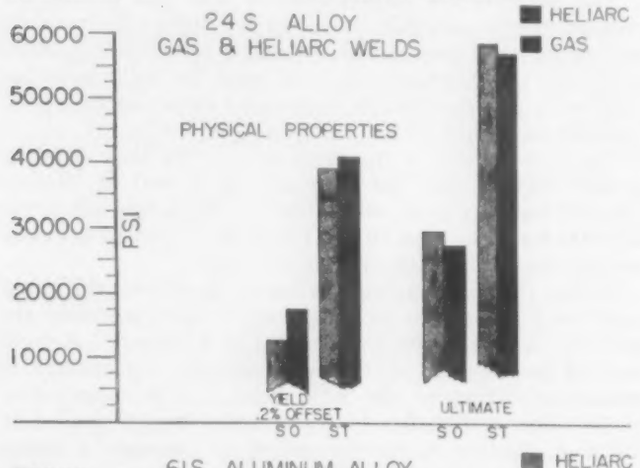


Fig. 11





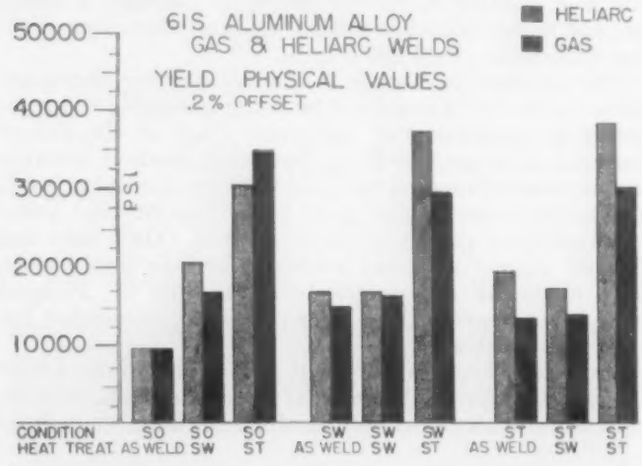


Fig. 12—(Top); Fig. 13 (Center); Fig. 14 (Bottom)

increase in the yield values when the Heliarc process is used. The average manual welding speeds with Heliarc, range from 6 to 30 in. per minute which is approximately three times faster than gas welding when using the flange butt welding method. All aluminum alloys may be satisfactorily Heliarc welded with equal or higher weld strengths than have ever been realized by other welding processes. Satisfactory Heliarc welds have been produced on 2S, 3S, 52S, 61S, 24S and 75S wrought aluminum sheet materials. See Figs. 10 to 14.

Fig. 15—Carburetor Preheat Manifold

All types of joints except fillet welds are satisfactorily made on aluminum alloys with the Heliarc process in production and has proved to be three times faster than gas welding.

Stainless steel has heretofore been the most difficult alloy to weld. However, it is satisfactorily arc, gas and atomic hydrogen welded but then only on thicker sections. Heliarc welding by use of argon gas has proved to be a superior method of welding stainless steel. The procedure consists of a torch containing a carbon or tungsten electrode around which flows argon gas. This argon gas blankets the molten weld metal, acts as a flux and prevents oxidation. A standard d.-c. generator of 150 amp. capacity is sufficient for most stainless steel sheet material. See Fig. 15.

Stainless steel sheet as thin as 0.010 in. may be welded by the Heliarc process producing a sound perfect weld, an equivalent of which is not possible by any other method of welding. The Heliarc welding method controls the degree of carbide precipitation and width of the heat-affected zone to the minimum and eliminates splatter and roughness. By maintaining a narrower heat-affected zone between the temperatures of 800–1500° F. the corrosion-resisting quality of the original material across the zone of the weld is preserved to the fullest extent possible.

Copper and copper alloys such as "Everdure" are successfully welded by the Heliarc process in our production line. Satisfactory physical properties have been produced in our laboratories indicating that a much broader application for this method of welding is possible where copper and its alloys require joining.

Railroad Tank Cars of All-Welded Aluminum

By R. E. Haas*

AMONG the many progressive steps to be noted lately in the field of metal fabrication, the welding of aluminum structures has created a great deal of interest in a variety of industries.

One of the largest and most unusual jobs of aluminum welding for which Lincoln equipment was recently installed is the fabrication of all-aluminum tank cars for the chemical industry. The work which is being done by General American Transportation Corp. of Sharon, Pa. consists of building a number of these tanks of preformed pieces of 3-S aluminum having thicknesses of $^1/_2$ in. and $^9/_{16}$ in.

Construction of the 31-ft., 4-in. long by 87-in. diameter structures to rigid specifications is made possible by the automatic carbon arc process and manual welding with metallic aluminum electrodes.

The tank shell is made up of three pieces of formed aluminum, square sheared and butted to form a joint with a gap of about $^1/_{32}$ in. and no greater than $^1/_{16}$ in.

The joints are first tack welded on the inside as shown in Fig. 1, using a 5% silicon aluminum shielded arc electrode. Intermittent welds approximately 4 in. in length were applied about 5 in. apart. A small square or tab of aluminum was also tacked to the edge of the shell at each end of the joint to be used later in starting and ending the continuous bead in the automatic carbon arc-welding operation.

* Welding Engineer, The Lincoln Electric Co., Cleveland, Ohio. Mr. Haas is Welding Engineer located at Warren, Ohio.

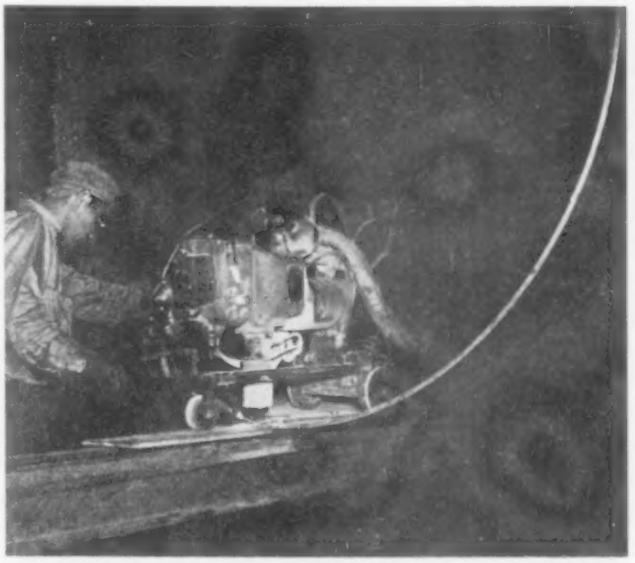


Fig. 3—Close-up of "Electronic Tornado" Tractor Outfit Showing Back-up Bar and Channel Holding Arrangement Used in Applying Continuous Weld Bead

The shell is then placed on a fixture and supported by four rubber-tired wheels so that the tank can be revolved for correct positioning of the seams. The automatic carbon arc known as "Electronic Tornado" is

Fig. 1—Tack Welding the Formed Aluminum Sheet Sections for Tank Shell Construction

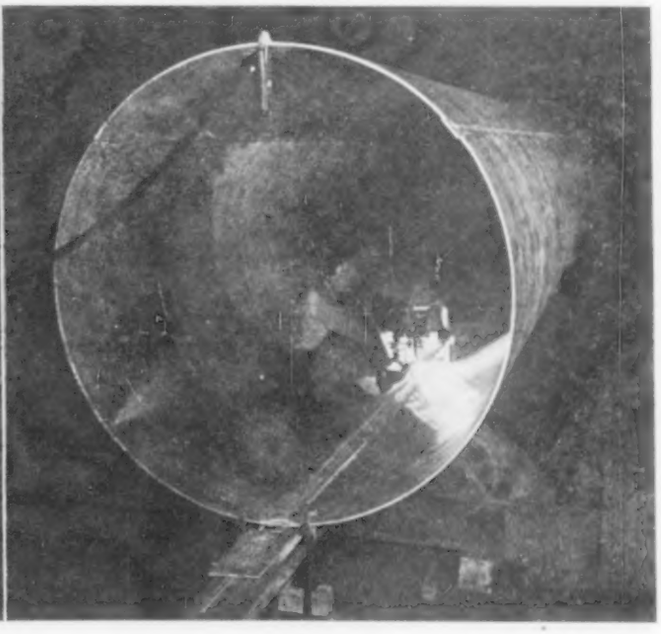


Fig. 2—Automatic Carbon Arc Welding the Inside, Longitudinal Seam of the Shell Structure

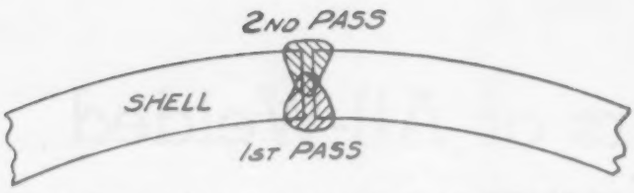


Fig. 4—Cross-sectional View of Longitudinal Shell Joint Showing Bead Penetration

then brought into use for applying a solid bead to the inside longitudinal joints.

A copper back-up bar, 3 in. in width and $^1/_2$ in. thick, is placed along the outside of the joint, being held tightly against the joint with a fire hose inflated with air at about 28 lb. pressure. The hose is positioned along the length of the joint under the back-up bar, and a channel frame arrangement. Figure 2 shows the automatic carbon arc welding in progress as the tractor-mounted equipment moves along the joint.

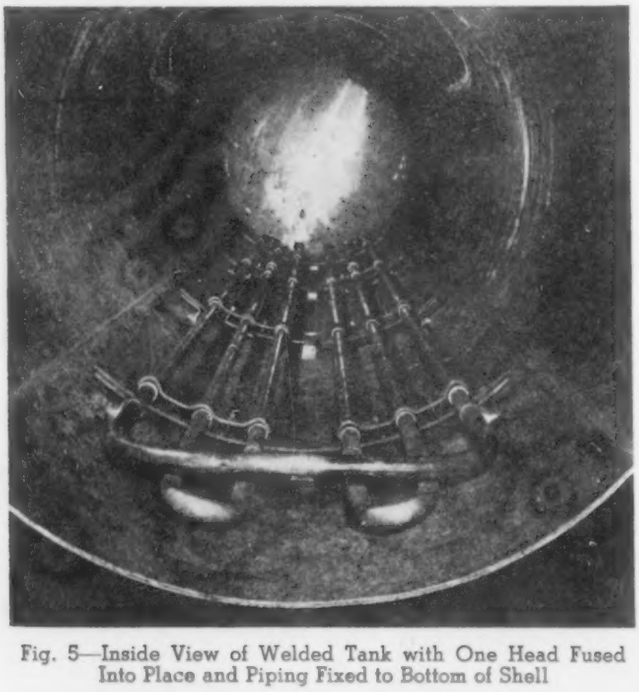


Fig. 5—Inside View of Welded Tank with One Head Fused Into Place and Piping Fixed to Bottom of Shell

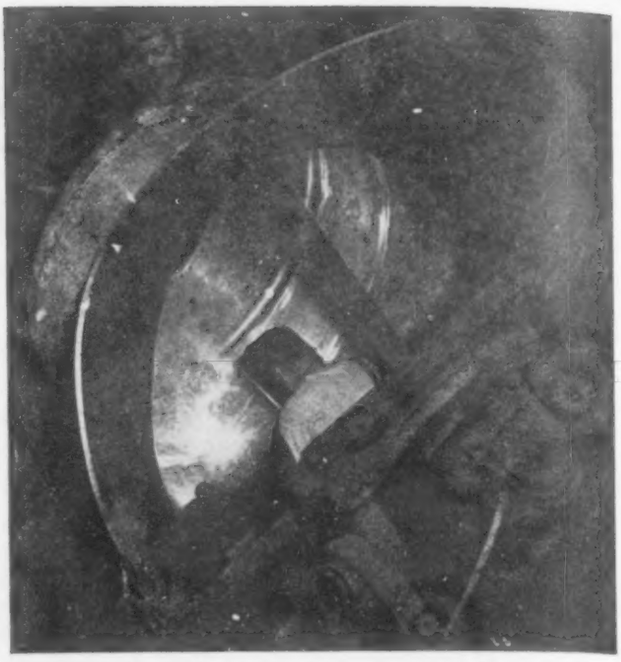


Fig. 6—Welding the Tank Dome by Hand Metallic Arc Process

A close-up of the machine is seen in Fig. 3 just after it has completed the welding of an inside joint. Weld penetration averages about three-fourths of the joint using $^3/_{16}$-in., 3-AS aluminum filler wire electrode and No. 520 flux; travel speed of the tractor unit is about 12 in. per minute with wire-feed rate of about 18 in. per minute; 430 amp., 32 volts was used at arc.

The same general automatic welding procedure is used in applying the outside beads on the longitudinal joints except that in this case no back-up bar is required, the weld metal penetrating the joint about 75% and fusing with the weld metal made on the first inside pass. (See cross-sectional view of welded shell joint, Fig. 4.)

The resultant joint averaged about 11,200 lb. tensile strength and an elongation of 41% in 2 in. X-ray tests showed no porosity.

After completing the shell fabrication, the two aluminum heads or ends of the tank having the same specifications, are then tacked into place with $^3/_{16}$-in. metallic electrodes of 5% silicon aluminum alloy, specially made

Fig. 7—Cleaning Finished Automatic Weld Bead with Power Wire Brush. Note Hand Welds on Dome Structure

Fig. 8—General View of Shop Assembly and Fabrication of Tank Car Units

for welding aluminum in any form. A 300-amp., 22-volt arc is used for this work. Finish welding is done after preheating the work to 600° F. to obtain more than the 30% elongation specified using 1/4-in. rod of above specifications with a 400-amp., 28-volt arc.

The outside of the joints for the heads were then welded with the "Electronic Tornado" process, using the same procedure as for the second (outside) pass on the longitudinal welding of the shell.

An inside view of a completed shell with one head or end piece in place is shown in Fig. 5. Pre-fabricated coils of aluminum piping used as a heating element for the contents of the tank are also seen in this view.

Domes are tacked and welded on the tank with the aluminum alloy shielded arc rod as described above. Both inside and outside beads are applied to the joints with the same procedure as used for the inside welding of the heads as previously explained. Figure 6 shows this work in progress. The operator seen at top in this view preheats the work by flame to 600° F. prior to welding. The entire dome is held and positioned on a power-operated positioning fixture, a portion of which is visible at lower right.

The outside brackets are welded to the shell with 1/4-in. electrodes for hand welding aluminum.

Figure 7 shows a close-up of the completely welded tank during cleaning of the weld beads with a wire power brush. Both automatically welded and hand-welded joints are clearly seen in this photo.

Power for the automatic welding is supplied by two 400-amp. welding generators connected in parallel with adjacent control box and panel for regulating the current.

A general idea of the best arrangement for maximum efficiency in welding these large aluminum tank car structures is indicated in the over-all view of the shop assembly and fabricating area seen in Fig. 8.

The manual welding as described above can also be accomplished by using the manual carbon arc process with filler metal supplied by the previously mentioned electrodes designed for hand welding of aluminum.

Some Conclusions Regarding Resistance Welding and Statistical Quality Control

By John Bayard Butler*

INSPECTION techniques applied to quantity production control must strike a balance between allowable unit inspection cost and possible harmful effects of incorporating scrap parts in the production output. The presence of scrap in the production output may be eliminated by inspecting each unit, but one hundred per cent inspection is seldom economically desirable and may not be used in cases where inspection methods destroy the part. If one hundred per cent inspection is not used the quality of the output must be judged by examination of a few units taken from the total output. When the method of manufacture obeys certain laws basic in the theory of sampling, statistical quality control presents the most logical and convenient method of establishing a sampling technique.

In the absence of simple, accurate nondestructive inspection methods for resistance welds the output from many resistance-welding machines is controlled by destructive testing of a certain proportion of the output. This type of inspection attempts to infer the characteristics of a large group of items called a universe, from the characteristics of a smaller group called a sample. The question of how small a group of items should be taken for a sample and what inferences concerning the universe can be drawn from examination of the sample is a matter of logical and mathematical analysis of the data. The question as to whether the data are typical or not determines whether sampling procedures can be used.

For a group of items to be typical two precautions must be taken. First, all the items of the universe

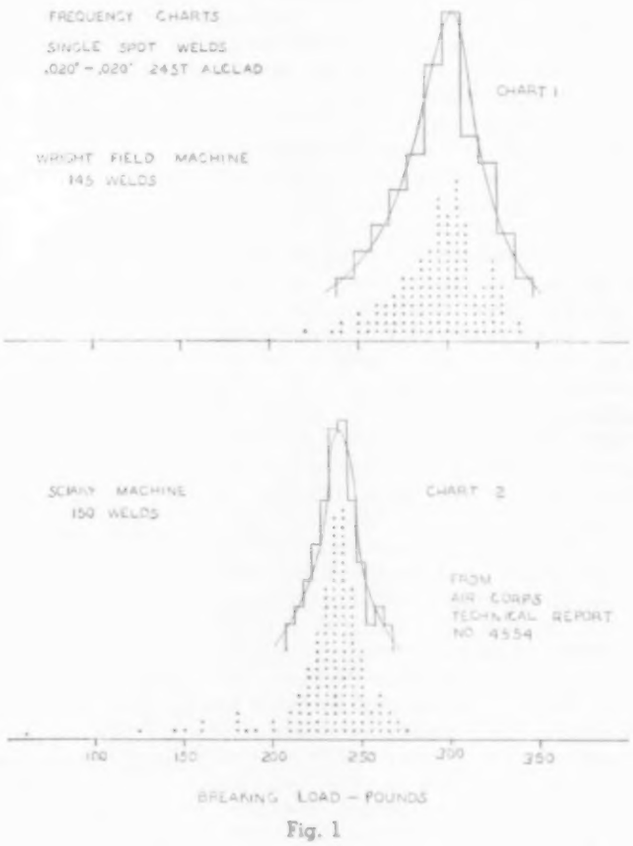


Fig. 1

* Test Engineer, Hamilton Standard Propellers, E. Hartford, Conn.

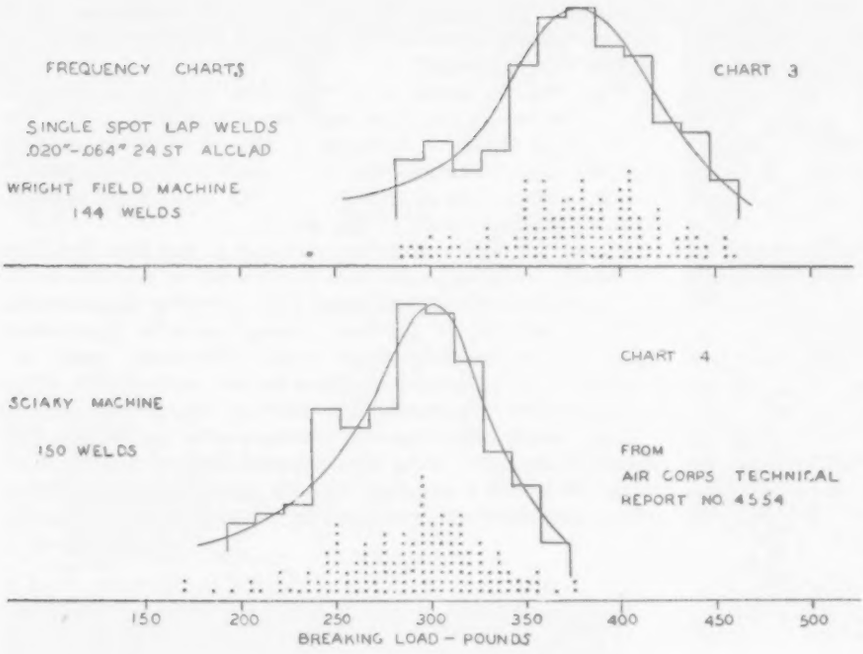


Fig. 2

studied must be susceptible to the same classifications; for example, spot welds from a stored energy machine must not be classed in the same universe as welds from an alternating-current machine. Second, the choice of a sample must be without bias. The inspector must not choose only those spot welds which have a related property such as tip pickup, burned spot or spatter. Thus to be able to make inferences that mean anything there must be an adequate random sample from a uniform universe.

To obtain the second condition, an unbiased sample, it is necessary that the items in the sample be selected in a truly random fashion. Although this may be difficult it is a process over which complete control can be maintained and the exercise of reasonable care should produce an unbiased sample.

To obtain condition number one, a uniform universe, a certain amount of control can be exerted by the welding engineer or supervisor. Before the samples are drawn from the universe it can be ascertained that all the welds in the universe come from the same machine, were made by the same shift, were made of the same stock and, in short, were subject to no known major variables. For the sampling technique to be successful there must be no variation between samples caused by predominant variables among the large number of variables acting upon the universe.

Examination of resistance welding in the light of these conditions discloses no difficulties which would preclude the use of statistical quality control. However, it is impossible to determine the characteristics of a universe by speculation, and in order to determine the quality of welds produced by resistance-welding machines it is desirable to study samples of welds taken from several universes. In order to obtain samples for analysis from different universes groups of spot welds were used which came from different machines and which were made using different gage sheet.

Inspection techniques correctly used to control production spot welds result in the actual measurement of shear strength for the specimens in the sample and from these measurements can be obtained a frequency distribution or curve relating shear strength to number of specimens of that particular shear strength. From a frequency distribution can be obtained an indication as to whether the variations between items result from a large number of causes none of which is predominant or from one or more major variables. If it can be proved that the results are influenced by a large number of small variables, a normal law distribution can be assumed, certain characteristics of the universe computed against which future samples may be compared, and the general laws of probability as used in statistical quality control may be applied.

It is the purpose of this paper to show how the presence of predominant variables may be ascertained and to present several examples of spot-weld data showing frequency distributions with no predominant variable and in one case a distribution with a predominant variable. It will be demonstrated that groups of spot welds containing over 100 welds can be made under the influence of no predominant variable. If it can be assumed that spot welds can be produced in industry with the same control of variables obtained in the tests studied then it may be said that quality control based upon the normal curve assumption may be applied to spot-welded joints. No attempt is made in this paper to outline the possible systems of quality control, as it is felt that that portion of the problem must be adjusted by each company to fit the particular problem involved.

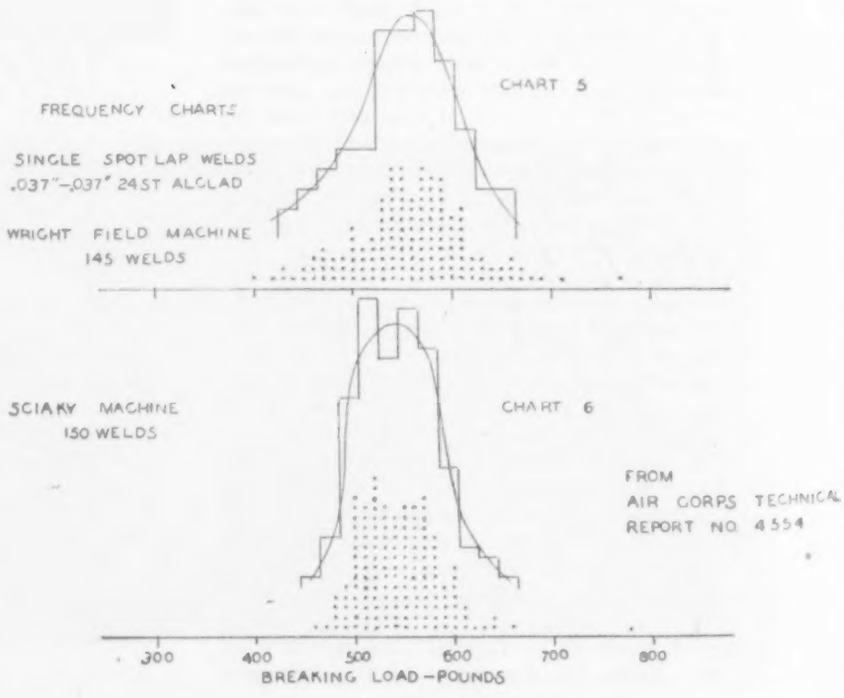


Fig. 3

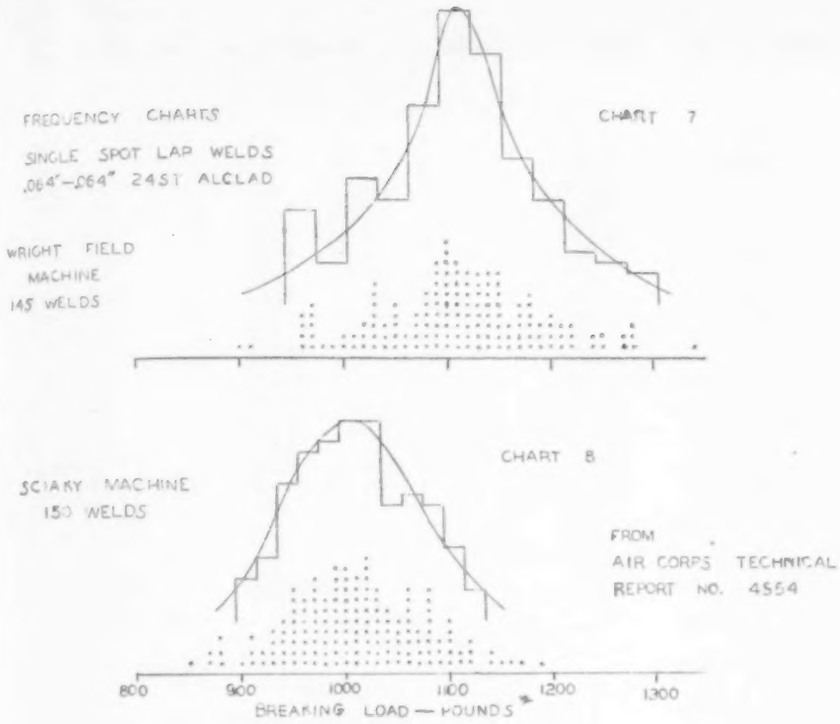


Fig. 4

These curves from the Air Corps Technical Report have been made by grouping the shear stress measurements into cells bounded by two shear stress values. The number and, therefore, the size of these cells were established by Messrs. Bowman and Ego and no change in cell size has been made in this paper.

A visual inspection of these curves disclosed a marked tendency toward grouping about an average value to form a distribution similar to a normal curve. The frequency curves are not smooth, but this may be caused not only by the relatively few number of items in each sample but by the choice of cell size. However, it may be assumed that the investigators made some attempt at finding the best cell size, although they were not particularly interested in the handling of absolute data. It is interesting to note Curve 2, Fig. 1, where eleven of the points were below 180 lb. breaking load, while the curve peak was at 240 lb., and there were no values above 275 lb. A study of this peculiarity leads to the belief that

The spot-weld data used in this paper were taken from an Air Corps Technical Report Number 4554 entitled "Tests of Sciaky PMCO 2S Spot Welder" conducted by R. E. Bowman and R. W. Ego, July 24, 1940. The data consisted of frequency charts of single spot shear specimens of various thicknesses welded on a Sciaky PMCO 2S Spot Welder and others obtained from a single-phase alternating-current spot welder belonging to the engineering shop at Wright Field.

Distribution curves for single spot shear tests on various thicknesses of 24ST Alclad are shown in Figs. 1 to 4.

Table 1—Single Spot Lap Welds. 0.020–0.020 24ST Alclad—5 Pounds Interval

Wright Field Alternating-Current Spot Welder

X	F	Fx	Fx^2
222.5	1	222.5	49,506.25
232.5	1	232.5	54,056.25
242.5	2	485.0	117,612.50
252.5	5	1,262.5	318,781.25
262.5	8	2,100.0	551,250.00
272.5	12	3,270.0	891,075.00
282.5	16	4,520.0	1,276,900.00
292.5	26	7,605.0	2,224,462.50
302.5	32	9,680.0	2,928,200.00
312.5	18	5,625.0	1,757,812.50
322.5	15	4,837.5	1,560,093.75
332.5	7	2,327.5	773,893.75
342.5	2	685.0	234,612.50
Total	145	42,852.5	12,738,256.25

$$\bar{X} = \frac{42,852.5}{145} = 295.53$$

$$\mu_Y = \frac{12,738,256.25}{145} = 87,850.04$$

$$\mu = 87,850.04 - (295.53)^2 = 512.06$$

$$\sigma = \sqrt{512.06} = 22.63$$

$$\bar{X} \pm 3\sigma = 295.53 \pm 67.89$$

144 out of 145 items in this range

or

99.31% of the items are in range $\bar{X} \pm 3\sigma$

Table 2—Single Spot Lap Welds. 0.020–0.020 24ST Alclad—5 Pounds Interval

Sciaky Type PMCO 2S Spot Welder

X	F	Fx	Fx^2
60	1	60	3,600
125	1	125	15,625
130			
135			
140			
145	1	145	21,025
150	1	150	22,500
155			
160	2	320	51,200
165			
170			
175			
180	3	540	97,200
185	1	185	34,225
190	1	190	36,100
195			
200	2	400	80,000
205			
210	3	630	132,300
215	5	1,075	231,125
220	8	1,760	387,200
225	12	2,700	607,500
230	17	3,910	899,300
235	25	5,875	1,380,625
240	26	6,240	1,497,600
245	17	4,165	1,020,425
250	10	2,500	625,000
255	3	765	195,075
260	5	1,300	338,000
265	3	795	210,675
270	2	540	145,800
275	1	275	75,625
Total	150	34,645	8,107,725

$$\bar{X} = \frac{34,645}{150} = 230.97$$

$$\mu_Y = \frac{8,107,725}{150} = 54,051.50$$

$$\mu = 54,051.50 - (230.97)^2 = 704.36$$

$$\sigma = \sqrt{704.36} = 26.54$$

$$\bar{X} \pm 3\sigma = 230.97 \pm 79.62$$

146 out-of 150 items in this range

or

97.33% of the items are in range $\bar{X} \pm 3\sigma$

Table 3—Single Spot Lap Welds. 0.020–0.064 24ST Alclad—15 Pounds Interval

Wright Field Machine

X	F	Fx	Fx^2
230	1	230	52,900
245			
260			
275			
290	6	1,740	504,600
305	8	2,440	744,200
320	5	1,600	512,000
335	7	2,345	785,575
350	16	5,600	1,960,000
365	21	7,665	2,797,725
380	22	8,360	3,176,800
395	18	7,110	2,808,450
410	17	6,970	2,857,700
425	10	4,250	1,806,250
440	9	3,960	1,742,400
455	4	1,820	828,100
Total	144	54,090	20,576,700

$\bar{X} = \frac{54,090}{144} = 375.63$

$\mu_Y = \frac{20,576,700}{144} = 142,893.75$

$\mu = 142,893.75 - (375.63)^2 = 4093.02$

$\sigma = \sqrt{1795.86} = 42.37$

$\bar{X} \pm 3\sigma = 375.63 \pm 127.11$

143 out of 144 items in this range

or

99.30% of the items are in range $\bar{X} \pm 3\sigma$

some major variable has influenced the low welds shown in Curve 2. The Air Corps Technical Report substantiates this deduction for on pages 18 and 19 there appears the following statement: "It will be noted that the welding conditions which would produce good welds in the 0.020-in. to 0.020-in. thickness of sheet were rather difficult to obtain and maintain on the Sciaky machine; the settings apparently are critical and do not allow much variation in sheet material or condition of electrodes. In this group, Chart 6, Fig. 3, the specimens with a breaking strength of less than 180 lb. were among the first thirty welded. All other specimens had good consistency. It was felt that a change in the welding conditions, a result of tip dressing, surface condition of the sheet, or some variation in the machine was responsible for the low strength of the first thirty welds."

A mathematical analysis of the frequency curves depends upon a theorem developed by Tchebzcheff and

Table 4—Single Spot Lap Welds. 0.020–0.064 24ST Alclad—15 Pounds Interval

Sciaky Type PMCO 2S Spot Welder

X	F	Fx	Fx^2
170	2	340	57,800
185	1	185	34,225
200	3	600	120,000
215	4	860	184,900
230	5	1,150	264,500
245	15	3,675	900,375
260	13	3,380	878,800
275	15	4,125	1,134,375
290	26	7,540	2,186,600
305	25	7,625	2,325,625
320	20	6,400	2,048,000
335	11	3,685	1,234,475
350	7	2,450	857,500
365	1	365	133,225
380	2	760	288,800
Total	150	43,140	12,649,200

$\bar{X} = \frac{43,140}{150} = 287.60$

$\mu_Y = \frac{12,649,200}{150} = 84,328.00$

$\mu = 84,328.00 - (287.60)^2 = 1614.24$

$\sigma = \sqrt{1614.24} = 40.18$

$\bar{X} \pm 3\sigma = 287.60 \pm 120.54$

150 out of 150 items in this range

or

100% of the items are in range $\bar{X} \pm 3\sigma$

Table 5—Single Spot Lap Welds. 0.037–0.037 24ST Alclad—20 Pounds Interval

Wright Field Alternating-Current Spot Welder

X	F	Fx	Fx^2
395	1	395	156,025
415	1	415	172,225
435	3	1,305	567,675
455	5	2,275	1,035,125
475	7	3,325	1,579,375
495	9	4,455	2,205,225
515	9	4,635	2,387,025
535	21	11,235	6,010,725
555	21	11,655	6,468,525
575	23	13,225	7,604,375
595	18	10,710	6,372,450
615	11	6,765	4,160,475
635	5	3,175	2,016,125
655	5	3,275	2,145,125
675	3	2,025	1,366,875
695	1	695	483,025
715	1	715	511,225
735			
755			
775	1	775	600,625
Total	145	81,055	45,842,225

$\bar{X} = \frac{81,055}{145} = 559.00$

$\mu_Y = \frac{45,842,225}{145} = 316,153.28$

$\mu = 316,153.28 - (559.00)^2 = 3672.28$

$\sigma = \sqrt{3672.28} = 60.60$

$\bar{X} \pm 3\sigma = 559.00 \pm 181.80$

144 out of 145 items in this range

or

99.31% of the items are in the range $\bar{X} \pm 3\sigma$

Table 6—Single Spot Lap Welds. 0.037–0.037 24ST Alclad—20 Pounds Interval

Sciaky Type PMCO 2S Spot Welder

X	F	Fx	Fx^2
455	1	455	207,025
475	5	2,375	1,128,125
495	19	9,405	4,655,475
515	29	14,935	7,691,525
535	23	12,305	6,583,175
555	28	15,540	8,624,700
575	24	13,800	7,935,000
595	12	7,140	4,248,300
615	4	2,460	1,512,900
635	3	1,905	1,209,675
655	1	655	429,025
775	1	775	600,625
Total	150	81,750	44,825,550

$\bar{X} = \frac{81,750}{150} = 545.00$

$\mu_Y = \frac{44,825,550}{150} = 298,837.00$

$\mu = 298,837.00 - (545.00)^2 = 1812.00$

$\sigma = \sqrt{1812.00} = 42.57$

$\bar{X} \pm 3\sigma = 545.00 \pm 127.71$

149 out of 150 items in this range

or

99.33% of the items are in the range $\bar{X} \pm 3\sigma$

Table 7—Single Spot Lap Welds. 0.064–0.064 24ST Alclad—30 Pounds Interval

Wright Field Alternating-Current Spot Welder

X	F	Fx	Fx^2
900	2	1,800	1,620,000
930			
960	9	8,640	8,294,400
990	4	3,960	3,920,400
1020	12	12,240	12,484,800
1050	10	10,500	11,025,000
1080	19	20,520	22,161,600
1110	28	31,080	34,498,800
1140	24	27,360	31,190,400
1170	14	16,380	19,164,600
1200	10	12,000	14,400,000
1230	5	6,150	7,564,500
1260	4	5,040	6,350,400
1290	3	3,870	4,992,300
1320			
1350	1	1,350	1,822,500
Total	145	160,890	179,489,700

$$\bar{X} = \frac{160,890}{145} = 1109.59$$

$$\mu_Y = \frac{179,489,700}{145} = 1,237,860.00$$

$$\mu = 1,237,860.00 - (1109.59)^2 = 6670.03$$

$$\sigma = \sqrt{6670.03} = 81.67$$

$$\bar{X} \pm 3\sigma = 1109.59 \pm 245.06$$

145 out of 145 times in this range

or

100% of the items are in the range $\bar{X} \pm 3\sigma$

generalized by Camp* and Meidel.† Tchebzcheff's theorem states that for any distribution of a single variable more than $100 \times (1 - (1/t^2))$ per cent of observations lie within the closed range $\bar{X} \pm t\sigma$ where:

t is any integer.

n is number of items in the sample.

$X_1, X_2, X_3, \ldots X_n$ are abscissae of distribution curve.

$f_1, f_2, f_3, \ldots f_n$ are frequencies at point $X_1, X_2, X_3, \ldots X_n$.

$\bar{X} = \frac{1}{n} \sum_{i=1}^{n} X_i f_i$ is arithmetic mean of distribution.

$\mu_Y = \frac{1}{n} \sum_{i=1}^{n} X_i^2 f_i$ is second moment about Y axis.

$\mu = \mu_Y - \bar{X}^2$ is second moment about $\bar{X}$.

$\sigma = \sqrt{\mu}$ is standard deviation.

It can be seen that σ is actually the radius of gyration of a flat body of n equal particles at varying distances from the center. The standard deviation σ may also be thought of as the root mean square of the data about the centroid. The Camp-Meidel extension of the Tchebzcheff formula states that for a unimodal distribution decreasing constantly from modal value to infinity more than $100\left(1 - \frac{1}{2.25t^2}\right)$ per cent of the items lie within the range $\bar{X} \pm t\sigma$.

The general comment of the Committee on Methods of Testing of The American Society for Testing Materials is of interest.‡ "Experience with frequency distributions for physical characteristics of materials and manufactured products prompts the Committee to insert a comment at this point. We have yet to find an observed frequency distribution of over 100 observations of a quality characteristic and purporting to represent essentially uniform conditions, that has less than 96% of its values within the range $\bar{X} \pm 3\sigma$." Substituting $t = 3$ in the Camp-Meidel inequality, $100\left(1 - \frac{1}{2.25 \times 9}\right) = 95\%$, discloses that the Committee on Testing has checked the inequality experimentally.

The Committee on Methods of Testing also gives the inequality for perfectly controlled conditions (normal distribution) the percentage of observations in the original sample lying in the range $\bar{X} \pm 3\sigma$ being 99.73%. By comparing the percentages of observations in the range $\bar{X} \pm 3\sigma$ for any distribution with the 99.7% value obtained from the Normal Law integral, with the 96% value listed by the Committee, and with the 95% obtained by Camp and Meidel, it is possible to obtain an excellent indication of how carefully the conditions were controlled in the universe and how well the sample was selected, as well as obtain some indication as to how closely the distribution can be approximated by a normal curve.

Data from the eight frequency curves from the Air Corps Technical Report have been tabulated in Tables 1 to 8 with observations grouped in the class intervals or cells for ease in handling. The shear strength reading measured from zero to the middle of the class interval is listed as X and the number of items in the class interval is listed as f. The values fX, fX^2, ΣfX, ΣfX^2, $\frac{\Sigma fX}{n}$, $\frac{\Sigma fX^2}{n}$ are listed on these pages while the values for μ and σ are calculated and $\bar{X} \pm 3\sigma$ is listed with the percentage of items in the distributions falling in this range also listed. The values of the arithmetic mean $\bar{X}$, the arithmetic mean plus or minus three times the deviation σ, per cent of the items of the distribution in this range, the Camp-Meidel number for $t = 3$, and the per cent in a Normal Curve, are tabulated below:

Sample	$\bar{X}$	$\bar{X} \pm 3\sigma$	% in Range	Camp-Meidel	Normal Law
Single Spot Lap Welds 0.020 In.–0.020 In. 24ST Alclad					
1. Wright Field Welder	295.5	295.5 ± 67.9	99.3	95	99.7
2. Sciaky Welder	231.0	231.0 ± 79.6	97.3	95	99.7
Single Spot Lap Welds 0.020 In.–0.064 In. 24ST Alclad					
3. Wright Field Welder	375.6	375.6 ±127.1	99.3	95	99.7
4. Sciaky Welder	287.6	287.6 ±120.5	100	95	99.7
Single Spot Lap Welds 0.037 In.–0.037 In. 24ST Alclad					
5. Wright Field Welder	559.0	559.0 ±181.8	99.3	95	99.7
6. Sciaky Welder	545.0	545.0 ±127.7	99.3	95	99.7
Single Spot Lap Welds 0.064 In.–0.064 In. 24ST Alclad					
7. Wright Field Welder	1109.6	1109.6 ±245.0	100	95	99.7
8. Sciaky Welder	1011.4	1011.4 ±198.1	100	95	99.7

Sample 2 is the only one of the group of eight frequency diagrams which fails to contain more than 99.3% of the items in the $\bar{X} \pm 3\sigma$ range. Although the value for Sample 2 is well above the Camp-Meidel value a comparison with the other seven samples indicates the presence of a predominant variable and confirms the visual examination of the data and the suspicions voiced in the Air Corps Technical Report.

Samples 1, 3, 4, 5, 6, 7 and 8 contain percentages of items well above the Camp-Meidel inequality and very close to the value for a normal curve. From the mathematical analysis of the distribution curves for Samples 1, 3, 4, 5, 6, 7 and 8 it might appear that these curves are actually normal curves unless it is remembered that similarity of a single characteristic of a distribution curve and a normal curve is not sufficient evidence to establish their identity. A visual comparison of these distribution curves with a normal curve will disclose numerous slight differences. However, the mathematical analysis of the

* Camp, B. H., "A New Generalization of Tchebzcheff's Statistical Inequality" *Bull. Am. Math. Soc.*, Vol. 28, 1922.

† Meidel, B., *Compt. Rend.*, Vol. 175.

‡ Committee E-1 on Methods of Testing, *A.S.T.M. Manual on Presentation of Data*, American Society for Testing Materials, August 1940.

Table 8—Single Spot Lap Welds. 0.064–0.064 24ST Alclad—20 Pounds Interval

Sciaky Machine

X	F	Fx	Fx^2
845	1	845	714,025
865	2	1,730	1,496,450
885	3	2,655	2,349,675
905	4	3,620	3,276,100
925	6	5,550	5,133,750
945	13	12,295	11,609,325
965	16	15,440	14,899,600
985	17	16,745	16,493,825
1005	19	19,095	19,190,475
1025	19	19,475	19,961,875
1045	11	11,495	12,012,275
1065	12	12,780	13,610,700
1085	11	11,935	12,949,475
1105	7	7,735	8,547,175
1125	3	3,375	3,796,875
1145	3	3,435	3,933,075
1165	2	2,330	2,714,450
1185	1	1,185	1,404,225
Total	150	151,710	154,093,350

$$\bar{X} = \frac{151{,}710}{150} = 1011.40$$

$$\mu_Y = \frac{154{,}093{,}350}{150} = 1{,}027{,}289.00$$

$$\mu = 1{,}027{,}289.00 - (1011.40)^2 = 4359.04$$

$$\sigma = \sqrt{4359.04} = 66.03$$

$$\bar{X} \pm 3\sigma = 1011.40 \pm 198.09$$

150 out of 150 items are in this range

or

100% of the items are in range $\bar{X} \pm 3\sigma$

data shows that a normal distribution may be assumed for purposes of further calculation.

The analysis of the data from these eight samples proves conclusively that spot welds can be produced with the Wright Field equipment whose shear strength values are only influenced by a large number of small causes. The fact that one sample showed the presence of a predominant variable is of interest in that it shows the sensitivity of this system of analysis. From these results it may be said that it is possible to set up the Wright Field welding equipment in such a fashion that the output may be controlled by statistical quality control.

Turning from the analysis of these specific data it is well to consider the application of these results to resistance welding in general. Although no machine or no department can be certified as producing welds free from predominent variable or variables without a study of a suitable sample from the output, it can be said that groups of resistance welds can be made whose strength characteristics closely approximate a normal grouping. Therefore users of resistance welding equipment should realize that they can apply statistical quality control to the output of their machines and should examine the possibility of using statistical quality control methods to improve their product and increase their output.

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Spot Welding of Heavy Aluminum Alloys

By C. W. Dodge†

PRODUCTION spot welding of aluminum alloys dates back only slightly over ten years. During this time the field has expanded from a handful of single-phase a.-c. welders to many hundred stored energy type machines. The first half of this period was limited to the welding of thinner sheets of the alloys because the tremendous low power factor demand required by the a.-c. machines when welding heavy sheets automatically prohibited their use for that purpose. The advent of stored energy machines in recent years has reduced the power supply problem to one of a secondary nature. Two main factors still existed, however, which retarded the progress of spot welding the heavier thicknesses. First was the lack of sufficient applications; second was the lack of knowledge of the problem. Both of these have been to a large extent eliminated during the past few years. The building of larger and larger aircraft has supplied enough applications so that if machines were readily available a considerable amount of heavy gage welding would be employed. Also an extensive amount of research has been performed recently, which has developed knowledge and data to such an extent that the problem has been reduced largely to one of size and cost of equipment.

Before going further let us define what we mean by heavy sheets. The complete range of thicknesses to which the spot welding of aluminum alloys has been commonly applied lies between 0.016 and 0.187 in. Below is a complete list of all the standard gages commonly used in aircraft.

Thin Sheets:	Normal Sheets:	Heavy Sheets:
0.016	0.040	0.102
0.020	0.045	0.114
0.025	0.051	0.125
0.032	0.064	0.156
	0.072	0.187
	0 081	
	0 091	

It will be noted that these are broken down into three divisions, thin, normal and heavy sheets. Until recently it has been generally considered that the welding characteristics of the three ranges were considerably different; the thin sheets being difficult to weld, the normal sheets being welded relatively easily, and the heavy sheets being very often extremely difficult to weld with any degree of satisfaction. This is due, not to any characteristic of the material, but rather to the limitations of existing welding equipment.

A term which will be used a great deal and which should be defined at this time is "optimum welding conditions." These are the conditions which in the opinion of the author will produce the best weld possible with the application of present-day technique. More specifically "optimum welding conditions" are those which produce a weld in aluminum alloys that conforms to the following specifications:

1. Four times the sheet thickness in diameter.
2. 60 to 70% penetration toward surface of sheet.
3. Free from noticeable heat-affected zone around the slug.
4. Possible to obtain up to 100 welds between tip cleanings.
5. Adjacent welds made at normal spacing with no noticeable shunting effect reducing the size and strength of the second weld.
6. Must be sound—entirely free from cracks, porosity, brittleness, etc., and sheet separation must be low.
7. Sheet indentation must be low.

Although all the data included in this article were gathered from tests made on aluminum clad 24ST welded on electromagnetic stored energy type equipment, random tests made on other alloys and on other types of equipment have indicated that there are basic laws governing the welding of all thicknesses which hold true for all alloys and machines.

The laws controlling the factors entering into the welding of the heavy sheets of aluminum alloys became apparent after three basic assumptions were made. Extensive tests then were made to prove whether the laws and assumptions were correct. These assumptions were:

1. In order to obtain the type of weld desired it is necessary that the slug be four times the sheet thickness in diameter.
2. It is possible to weld any thickness of aluminum alloys and obtain exactly the type of weld desired with exactly the same technique as for any other thickness providing certain basic laws are followed (see Fig. 5).
3. Welds made on 0.040-in. material with a machine whose range is 0.016 to 0.081 in. are made under the best possible conditions and that the magnitudes of all factors producing an optimum weld on this thickness may be used as the basis for all values determined for other thicknesses according to the laws developed.

These assumptions were made purely from a thorough study of empirical data gathered from experience in welding aluminum alloys over a long period of time. The first of the above forms the actual basis of all developments and was determined from observing that in all cases where the slug diameter of a completely satisfactory weld was greater than four times the sheet thickness, the latitude of machine adjustments was large, a large number of welds could be made between tip cleanings, and that consistency of size and strength was very good. Whenever the slug diameter was less than four times the sheet thickness, latitude of machine adjust-

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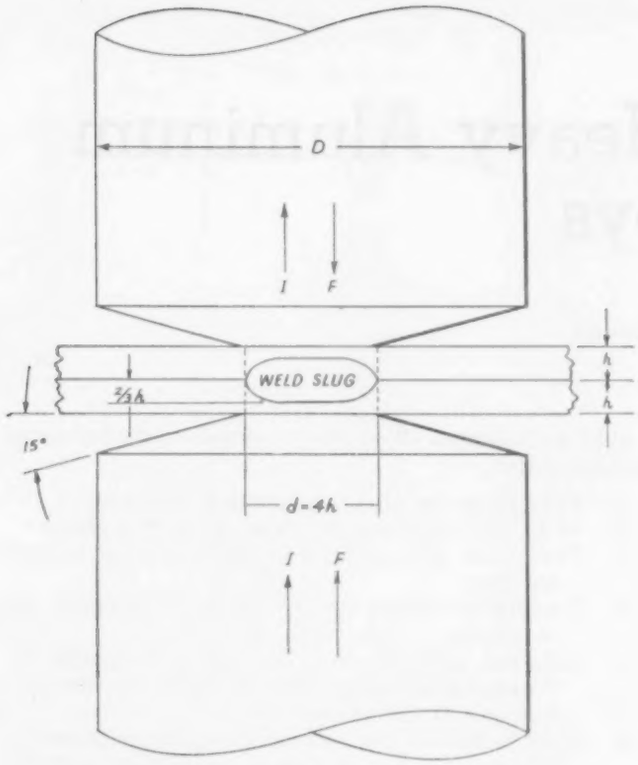


Fig. 1

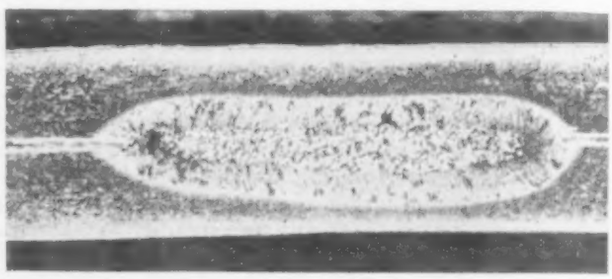
ments became narrow, tip cleaning was necessarily frequent, and consistency of size and shape were not always as good as desired. Although any value between four and six times the sheet thickness is apparently conducive to good welding conditions, welds greater than four times the sheet thickness naturally require larger magnitudes of heat and pressure and have been found to be unnecessary as far as strength is concerned. Therefore, the value four is considered to be optimum. Someone may well argue that for the heavy sheets this value gives a weld which is stronger than necessary from a structural point of view and which is larger than desired for design purposes of flange widths, etc. This is no doubt true; however, as will be shown later, it has been proved to the author's satisfaction that this value of four times the sheet thickness for slug diameter is optimum and highly desirable for producing welds on any thickness under high-speed satisfactory production conditions. This does not mean that welds smaller than this cannot be easily made. It does mean, however, that smaller welds are made at some sacrifice in other factors. Roughly 3.5 times the sheet thickness has been observed to be the absolute minimum size of weld which can be made without causing some factors to become extremely critical. This holds true more for the strong alloys than for the softer weaker ones.

The second assumption was made merely with the thought that nearly all processes in nature conform to certain laws and that changing dimensions of the material being welded should theoretically not have any effect on the weldability of the material but only on the magnitudes of the controlling factors.

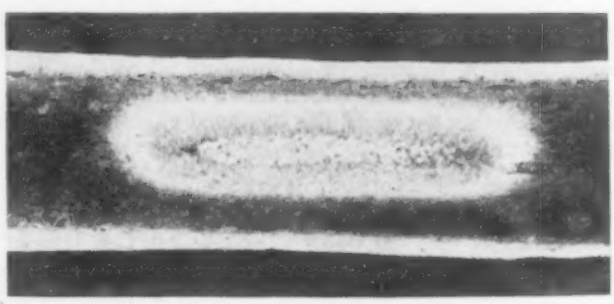
It has been observed for a long time that welds on 0.040-inch thick material seemed to be the easiest to produce with the widest latitude of machine adjustments on so-called standard size machines. They were mostly very consistent in both size and shape and gave a minimum amount of tip pickup. Also because 0.040 lies almost in the center of the operating range of most standard equipment, it was felt that the assumption of using the magnitudes of all factors which produced optimum welds on this thickness would not be far from wrong.

The table below contains all the data which are used in making an optimum weld on 0.040 on an electromagnetic stored energy type machine.

Material—clad 24ST
Thickness—0.040 + 0.040
Cleaning—Wire brush, both surfaces
Electrode diameter—$^1/_2$ in.
Electrode tip contour—2 in. radius or 0.160 in. flat with 15° approach angle
Maximum preheat current—6000 amp.



A
0.040+0.040-in. 24ST Alclad (d = 4.4h).



B
One sheet of 0.080-in. 24ST Alclad (d = 3.8h if h = 0.040 in.).

Fig. 3—Both Welds Made on Same Machine Using Same Settings. Indicates Resistance of Material Is Larger Factor in Making Weld Than Contact Resistance

Total preheat time—0.08 sec.
Peak welding current—18,000 amp.
Time to $^1/_2$ I max.—0.04 sec. (see Fig. 2)
Welding force between electrodes—500 lb.
Forging force between electrodes—1500 lb.

The above is the condition for variable pressure welding. If constant pressure welding is used the values of current and electrode force are as follows:

Maximum preheat current—8400 amp.
Peak welding current—25,200 amp.
Welding force between electrodes—900 lb.

All the other factors remain the same.

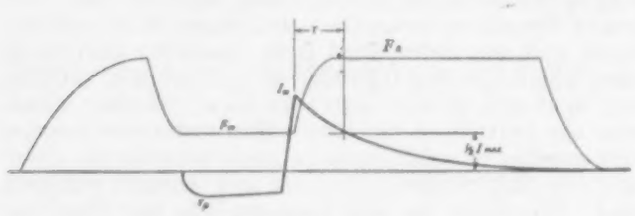


Fig. 2

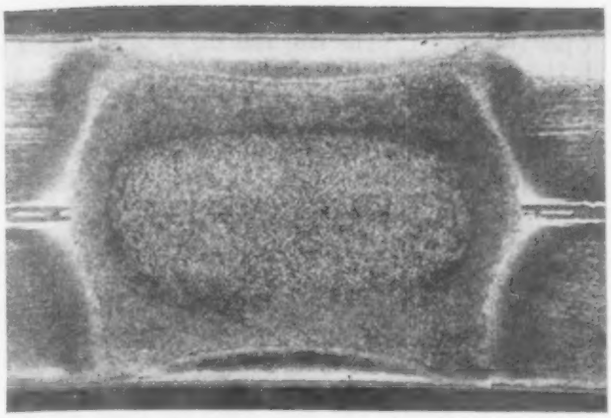


Fig. 4

0.187- + 0.187-in. 24ST Alclad welded with conditions slightly below that required for a weld ($d = 3h$). Shows excessive heat penetration causing rapid pickup on electrodes. Actually $d = 2.6h$.

It will be noted that the preheat current is $^1/_3$ the welding current and that the forging force is three times the welding force. Both of these are empirical values determined by experiment.

Before going further let us make one more assumption which is that all current passes through and all applied force acts upon a cylinder of metal which lies between the two electrodes and which is the same diameter as the diameter of the weld slug, i.e., four times the sheet thickness as illustrated in Fig. 1.

It will be noted that flat tips are shown in Fig. 1. For purposes of all our theoretical study they shall be used because dome tips produce conditions which are completely indeterminate. In actual practice, however, if correctly used, both flat and dome tips produce approximately the same results.

As stated before it has become apparent that there are certain laws governing the magnitudes of all factors entering into the spot-welding process as applied to aluminum alloys. Providing these laws are strictly observed it has been determined that these magnitudes may be expressed mathematically as functions of the thickness of the material being welded. The laws are given below as determined empirically or mathematically.

1. Electrode Force

The pressure required and exerted by the electrodes upon the sheets being welded is constant regardless of thickness for optimum welds. This means that the electrode force required is proportional to the weld area or to the square of the diameter. Expressed mathematically we have:

$$P = k = \frac{F_w}{A}$$

$$F_w = kA = \frac{k\pi d^2}{4}$$

but $d = 4h$, therefore

$$F_w = \frac{k\pi}{4} \times (4h)^2 = 4k\pi h^2$$

or in simplest form

$$F_w = Kh^2 \qquad (1)$$

The above applies to the welding force for both constant and variable pressure cycles although the value of K of course is different for the two conditions. For variable pressure cycle the optimum forging force has been found by experiment to be three times the welding force:

$$F_f = 3F_w \qquad (2)$$

2. Weld Resistance

The resistance of the weld zone or the cylinder of metal between the faces of the electrode tips is proportional to the reciprocal of the thickness:

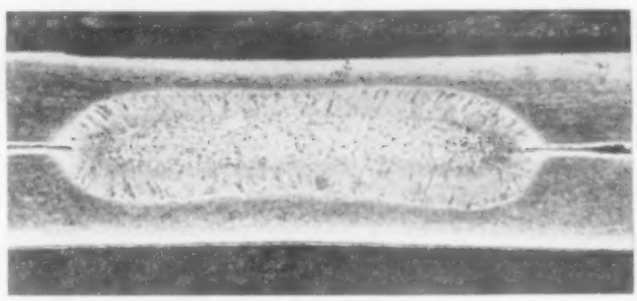
$$R = \frac{2\rho h}{A}$$

where ρ is the resistivity

$$R = \frac{8\rho h}{\pi d^2} = \frac{8\rho h}{16\pi h^2} = \frac{\rho}{2\pi} \cdot \frac{1}{h}$$

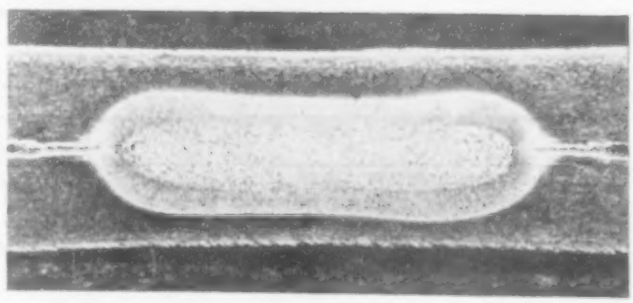
$$R = \frac{K}{h} \qquad (3)$$

It will be noted that the above neglects the contact surface resistance which we know has an appreciable magnitude under static conditions. Under actual welding conditions on wire brushed material, however, the contact resistance is believed to have little bearing on the



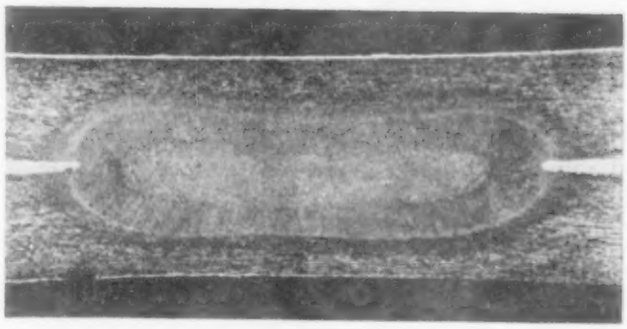
A

0.040 + 0.040-in. 24ST Alclad ($d = 4.4h$).



B

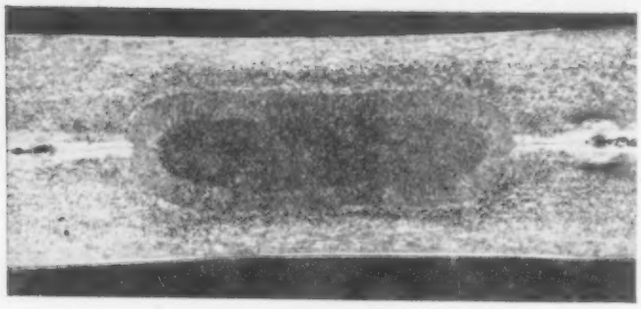
0.064 + 0.064-in. 24ST Alclad ($d = 4.2h$).



C

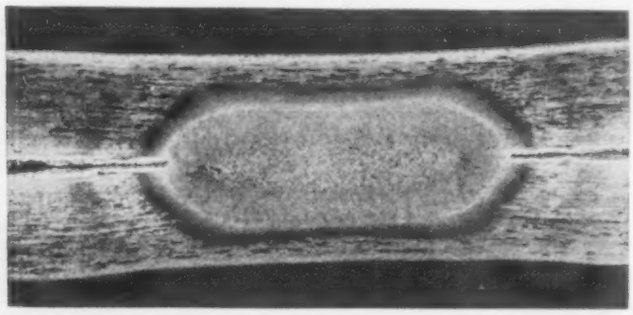
0.125 + 0.125-in. 24ST Alclad ($d = 4.1h$).

Fig. 5—Illustrating the Fact That "Optimum Welds" Appear Very Similar Regardless of Thickness



A

0.091- + 0.091-in. 24ST Alclad ($d = 3.2h$). Start of heat-affected zone extending toward surface may be seen.



B

0.125- + 0.125-in. 24ST Alclad ($d = 3h$). Definite amount of heat-affected zone surrounding slug.

Fig. 6

size or shape of the weld particularly on the heavier thicknesses. This has been verified experimentally by setting a machine to produce a definite size weld on two sheets of a given thickness. Then with the same machine settings one piece of material having a thickness equal to the total of the two sheets welded was placed between the electrodes and the resulting fused slug compared with that of the two sheets. The size and shape of each were approximately the same (see Fig. 3).

3. Welding Heat

The total heat required to produce a weld slug of a given diameter is proportional to the cube of the thickness. Although for long welding times a large amount of heat is conducted away into the surrounding sheet and into the electrodes in addition to the heat which is utilized in producing the weld slug, the welding time for aluminum alloys with stored energy equipment is so short that this conduction factor apparently becomes negligible.

If the weld nugget is always four times the sheet thickness in diameter and always a definite proportion of the thickness in height, the heat required from the above assumption should be proportional to the volume of the nugget.

$$Q = kV$$

$$V = {}^4/_3\pi a^2 b$$

for a circular ellipsoid which approximates the shape of a weld slug where,

$$a = {}^1/_2 d = 2h$$

$$b = {}^2/_3 h$$

$$V = {}^4/_3\pi(2h)^2({}^2/_3 h) = ({}^4/_3)({}^2/_3)(\pi)(4h^2)(h)$$

$$V = \frac{32\pi}{9} \times h^3$$

$$Q = k\left(\frac{32\pi}{9} h^3\right)$$

$$Q = Kh^3 \qquad (4)$$

4. Welding Time

The welding time or time to reach ${}^1/_2\ I$ max. (see Fig. 2) is directly proportional to the thickness.

$$T = Kh \qquad (5)$$

Table 1

FACTOR	EQUATION	ABSOLUTE MINIMUM d = 3h	PRACTICAL MINIMUM d = 3.5h	OPTIMUM d = 4h
1. Welding electrode force (constant)	$F_w=Kh^2$ lbs	$F_w=312{,}500h^2$	$F_w=437{,}500h^2$	$F_w=562{,}500h^2$
2. Welding electrode force (variable)	$F_w=Kh^2$ lbs	$F_w=125{,}000h^2$	$F_w=218{,}000h^2$	$F_w=312{,}500h^2$
3. Forging electrode force (variable)	$F_f=3F_w$ lbs			
4. Welding time (time to 1/2 I maximum)	T=Kh secs.	T=1/2h	T=3/4h	T=h
5. Welding current peak (constant)	$I_w=Kh^{3/2}$amps.	$I_w=2.25X10^6h^{3/2}$	$I_w=2.685X10^6h^{3/2}$	$I_w=3.125X10^6h^{3/2}$
6. Welding current peak (variable)	$I_w=Kh^{3/2}$amps.	$I_w=1.875X10^6h^{3/2}$	$I_w=2.125X10^6h^{3/2}$	$I_w=2.375X10^6h^{3/2}$
7. Preheat current maximum	$I_p=1/3I_w$amps.			
8. Electrode diameter	D=Kh in.	D=9.4h	D=9.4h	D=12.5h
9. Spot spacing	p=Kh in.	p=9.4h	p=12.5h	p=15.6h
10. Edge distance (from center of spot)	e=Kh in.	e=4.7h	e=6.3h	e=7.8h
11. Tip radius (dome tips)	r=Kh in.	r=25h	r=37.5h	r=50h
12. Shear strength	$S=Kh^2$in.	$S=187{,}500h^2$	$S=250{,}000h^2$	$S=312{,}500h^2$

Table 2—Absolute Minimum Value ($d = 3h$)

Thickness Combination (inches)	F_w Constant (lbs.)	F_w Variable (lbs.)	F_f Variable (lbs.)	T (Secs)	I_w Constant (amps)	I_w Variable (amps)	D (Inches)	p (Inches)	e (Inches)	r (Inches)	S (Inches
.016 + .016	56	32	96	.008	4550	3790	.150	.150	.075	.400	48
.020 + .020	88	50	150	.010	6360	5300	.188	.188	.094	.500	75
.025 + .025	137	78	234	.013	8990	7410	.235	.235	.117	.625	117
.032 + .032	224	128	384	.016	12900	10730	.301	.301	.151	.800	192
.040 + .040	350	200	600	.020	18000	15000	.376	.376	.188	1.000	300
.051 + .051	569	325	975	.025	25950	21600	.480	.480	.240	1.275	488
.064 + .064	896	512	1536	.032	36400	30350	.602	.602	.305	1.600	768
.072 + .072	1132	648	1944	.036	43500	36250	.676	.676	.339	1.800	973
.081 + .081	1432	820	2460	.040	51900	43250	.761	.761	.380	2.000	1230
.091 + .091	1810	1035	3105	.045	61800	51500	.855	.855	.428	2.250	1550
.102 + .102	2275	1300	3900	.051	73300	61050	.959	.959	.480	2.550	1950
.114 + .114	2840	1625	4875	.057	86700	72200	1.071	1.071	.535	2.825	2440
.125 + .125	3415	1950	5850	.063	99400	82750	1.175	1.175	.588	3.125	2930
.156 + .156	5250	3000	9000	.078	138800	115600	1.465	1.465	.730	3.900	4500
.187 + .187	7650	4370	13110	.093	182000	151800	1.758	1.758	.880	4.675	6560

This value has been determined empirically from a large number of tests.

5. Welding Current

The secondary peak current required for welding is proportional to the $^3/_2$ power of the thickness.

The total heat input to any electrical phenomenom is:

$$Q = I^2RT$$

but from Equation 4

$$Q = Kh^3$$

therefore

$$I^2RT = Kh^3$$

substituting the value of R and T in terms of h from equations 3 and 5 we have:

Table 3—Practical Minimum Values ($d = 3.5h$)

Thickness Combination (inches)	F_w Constant (lbs.)	F_w Variable (lbs.)	F_f Variable (lbs.)	T (Secs)	I_w Constant (amps)	I_w Variable (amps)	D (Inches)	p (Inches)	e (Inches)	r (Inches)	S (Inches
.016 + .016	112	56	168	.012	5430	4290	.150	.200	.101	.600	64
.020 + .020	175	88	264	.015	7590	6060	.188	.250	.126	.750	100
.025 + .025	274	137	411	.019	10630	8400	.235	.3125	.158	.938	156
.032 + .032	448	224	672	.024	15390	12180	.301	.400	.202	1.125	256
.040 + .040	700	350	1050	.030	21500	17000	.376	.500	.252	1.500	400
.051 + .051	1137	569	1707	.038	30950	24500	.480	.6375	.321	1.912	650
.064 + .064	1790	896	2688	.048	43400	34400	.602	.800	.403	2.400	1025
.072 + .072	2265	1132	3396	.054	51900	41100	.676	.900	.453	2.700	1295
.081 + .081	2879	1432	4296	.061	62000	49000	.761	1.012	.510	3.035	1640
.091 + .091	3620	1810	5430	.068	73750	58400	.855	1.138	.573	3.410	2070
.102 + .102	4550	2275	6825	.077	87450	69200	.959	1.275	.643	3.825	2600
.114 + .114	5690	2840	8520	.086	103500	81800	1.071	1.425	.718	4.280	3250
.125 + .125	6830	3415	10245	.094	118500	93800	1.175	1.5625	.788	4.690	3905
.156 + .156	10500	5250	15750	.117	165500	131000	1.465	1.950	.983	5.850	6000
.187 + .187	15300	7650	22950	.140	217500	172000	1.758	2.335	1.178	7.001	8740

$$I^2\left(\frac{K_1}{h}\right)(K_2h) = K_3h^3$$

$$I^2 = \frac{K_3h^3}{K_1K_2}$$

$$I = Kh^{3/2} \qquad (6)$$

6. Shear Strength

The shear strength is proportional to the shear area of the weld slug. Therefore, as in the derivation of Equation 1, the optimum shear strength is proportional to the square of the thickness.

$$S = Kh^2 \qquad (7)$$

7. Electrode Diameter

The electrode diameter required in order that the temperature rise in the electrode be the same for all thicknesses is directly proportional to the thickness.

The heat input to the electrode is:

$$Q = I^2RT$$

where R is the resistance of the electrode.

The heat absorbed in the electrode is:

$$Q = Mkc(t_2 - t_1)$$

where

M = mass
K = a constant depending on the units used
c = the specific heat
$t_2 - t_1$ = temperature rise

Now as we have decided that the temperature rise should be constant

$$t_2 - t_1 = \text{a constant}$$

$Q = MK_1$ as the specific heat (c) is essentially a constant for any given material over a small range of temperature, from this we have,

$$MK_1 = I^2RT \qquad (8)$$

$$M = slA = \frac{sl\pi D^2}{4}$$

where

s = density
l = length
D = diameter of electrode

We will assume the length (l) remains essentially constant regardless of the diameter which is nearly the actual case in most instances, also (s) is a constant for any given material. Therefore

$$M = K_2D^2$$

$$R = \frac{\rho l}{A} = \frac{4\rho l}{\pi D^2}$$

for the same reasons as above (e) and (l) are constant

$$R = \frac{K_3}{D^2}$$

now substituting in Equation 8 above we find,

$$K_2D^2 = (K_4h^{3/2})^2\left(\frac{K_3}{D^2}\right)(K_5h)$$

The values for I and T being from Equations 5 and 6.

$$D^2 = \frac{K_4^2h^3 \cdot K_3 \cdot K_5h}{K_2D^2} = K_7\frac{h^4}{D^2}$$

$$D^4 = K_7h^4$$

$$D = Kh \qquad (9)$$

8. Spot Spacing and Edge Distance

From the results of test data and logically from above these have both been found to be directly proportional to the thickness.

(*a*) *Spacing:*

$$p = Kh \qquad (10)$$

(*b*) *Edge Distance:*

$$e = Kh \qquad (11)$$

Table 4—Optimum Values ($d = 4h$)

Thickness Combination (inches)	F_w Constant (lbs)	F_w Variable (lbs.)	F_f Variable (lbs.)	T (Secs)	I_w Constant (amps)	I_w Variable (amps)	D (Inches)	p (Inches)	e (Inches)	r (Inches)	S (Inches)
.016 + .016	144	80	240	.016	6310	4800	.200	.250	.125	.800	80
.020 + .020	225	125	375	.020	8830	6710	.250	.312	.156	1.000	125
.025 + .025	352	195	586	.025	12360	9400	.3125	.390	.195	1.250	195
.032 + .032	576	320	959	.032	17900	13600	.400	.500	.250	1.600	320
.040 + .040	900	500	1500	.040	25000	19000	.500	.625	.312	2.000	500
.051 + .051	1463	813	2440	.051	36000	27350	.6375	.796	.398	2.550	813
.064 + .064	2305	1280	3835	.064	50600	38400	.800	1.000	.500	3.200	1280
.072 + .072	2915	1620	4860	.072	60400	45900	.900	1.125	.562	3.600	1620
.081 + .081	3685	2050	6150	.081	72100	54750	1.012	1.265	.640	4.050	2050
.091 + .091	4655	2585	7760	.091	85800	65250	1.138	1.425	.710	4.550	2585
.102 + .102	5850	3145	9750	.102	101800	77400	1.275	1.593	.796	5.100	3145
.114 + .114	7310	4060	12180	.114	120200	91500	1.425	1.781	.812	5.700	4060
.125 + .125	8790	4890	14650	.125	138000	105000	1.5625	1.953	.975	6.250	4890
.156 + .156	13680	7610	22800	.156	192600	144000	1.950	2.435	1.218	7.800	7610
.187 + .187	19660	10920	32800	.187	252500	192000	2.335	2.920	1.460	9.350	10920

9. Tip Radius

Results of test data also have indicated that the tip radius for dome tips is directly proportional to the thickness.

$$r = Kh \qquad (12)$$

It will be noted that the above equations do not take into account any particular material or slug diameter-thickness ratio. It is the author's belief from tests made on materials other than clad 24ST including some ferrous alloys that the above laws hold true for all cases. Practical considerations, however, alter the conditions to a large extent in many cases particularly on steel. Also the basic assumption that the optimum conditions exist when $d = 4h$ probably does not hold true for many other materials.

It is realized that considerable liberty has been taken with assumptions made and the complete reason for making the assumption in many cases is not known. However by making them the mathematical derivation agrees with the empirical, because for clad 24ST material the above have been found experimentally to be strictly correct with, as expressed before, $d = 4h$ as the optimum conditions, $d = 3.5\ h$ the minimum practical condition and $d = 3h$ as the absolute minimum (see Fig. 6).

The slug diameter has been found not to be a function entirely depending on the amount of current used but rather is determined by the correct relative magnitudes of all factors. If, for instance, an optimum weld is made having $d = 4h$ and an attempt is made to produce a weld where $d = 3.5h$ by reducing the current (I) leaving all other factors constant, it will be found that the penetration is reduced by a much higher percentage than the diameter and the consistency of successive spots suffers considerably. On the other hand if a good weld where $d = 3.5h$ has been produced with certain machine settings and an attempt is made to enlarge it to $d = 4h$, by increasing the current, the result again will be to increase the penetration more than the diameter and to initiate cracking and porosity within the slug.

Machine settings and the magnitudes of many of the above factors currently used in production do not conform to the above laws except in cases where the thickness being welded lies in approximately the center of the total welding range of the machine being used. This is not an indication that the laws cannot be applied practically, but rather it is an indication that some of the thicknesses are being welded on machines at a low degree of efficiency. In other words, the thicknesses which lie toward the low end of the range of a machine usually are welded with considerably too much pressure and heat because of the lack of sufficiently flexible machine adjustments or physical limitations. This means that spots currently made on 0.012, 0.016 and 0.020, for instance, usually are six or more times the sheet thickness in diameter which is undesirable when considering either efficiency or strength. A large number of spots having $d = 4h$ consistently should produce a more efficient joint with less buckling and with less effect on the heat-treated structure of the parent metal.

On the other hand the thicknesses which lie toward the upper end of the welding range of a machine are generally at best $3.5h$ in diameter because the maximum pressure, current and time available are too low for optimum conditions. This means that such spots are made at a low efficiency, all factors considered. The penetration of the slug and its surrounding heat-affected zone, not only is such that the metallurgical quality may be inferior to that of an optimum weld, but also causes heat penetration nearly to the surface of the material so that pickup on the electrodes may be quite severe (see Fig. 4). Also the separation of the sheets at the faying surfaces surrounding the weld may become difficult to control. Strength consistency is usually inferior to that of optimum welds and a tendency to expel metal from between the sheets often results. In addition, welds spaced at a normal distance will show a marked tendency for the second and succeeding welds to have a lower shear strength than the first, a condition which is of little or no consequence for optimum welds.

The above and the laws propounded herewith have been verified experimentally with hundreds of tests on aluminum alloys on different sized machines. A machine which has a guaranteed range of 0.016 to 0.081 will easily produce optimum welds on 0.032, 0.040 and 0.051 but not on 0.016 or 0.081. A machine whose guaranteed range is 0.032 to 0.125, on the other hand produces optimum welds on 0.064, 0.072 and 0.081 but not on 0.032 or 0.125. Likewise, a machine having a range of from 0.064 to 0.187 will produce optimum welds on 0.091 through 0.125 but not on 0.064 and 0.187. In every case, where the magnitudes of all factors of a machine could be adjusted to those desired as determined from the above laws to produce an optimum weld, the size and shape of the weld produced was exactly the same as that predicted and the latitude of all adjustments was very wide with little or none of the undesirable effects described above (see Fig. 5).

Table 1 contains values of K for each factor as expressed mathematically for $d = 3h$, $d = 3.5h$ and $d = 4h$ for both constant and variable pressure welding. Practically all of these values have been verified experimentally for the range of thicknesses from 0.032 to 0.125. Values for thicknesses below 0.032 have not been verified because no machine small enough has ever been made for the purpose. Likewise no machine large enough has ever been made for thicknesses above 0.125 to produce optimum welds.

Tables 2, 3 and 4 present actual values for each of the factors as calculated from the factors in Table 1.

They hit the Beaches with Welded Steel

A duck takes off from an LST on D-day at Iwo Jima. Mass production of these new implements of war, of the other vessels shown in the picture — and of countless other innovations on land, at sea and in the air — was made possible by improved technique and weld-tested steels.

U. S. Coast Guard Photo

THE MEN who have rolled up the war records in shipyards, munitions factories and plane plants can tell you that it takes quality steels with exceptional welding characteristics to turn out good work in record time.

Quality steels with exceptional welding characteristics . . . that's a good description of U·S·S Rolled Steels. These high quality steels have helped many manufacturers to hang up new production records.

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Perhaps our technical staff can help you. Why not discuss your welding problems with us? Write us today. This service is offered without obligation.

EVERY SUNDAY EVENING, United States Steel presents *The Theatre Guild on the Air*. American Broadcasting Company coast-to-coast network. Consult your newspaper for time and station.

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U·S·S HIGH STRENGTH STEELS *to resist atmospheric corrosion and increase strength without adding weight.*

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U·S·S CARILLOY ALLOY STEELS—*Special steels for the special jobs of industry.*

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USS STEEL

UNITED STATES STEEL

Some Fundamentals in All-Welded Ship Construction*

By Milton Forman†

THE Emergency Shipbuilding Program is drawing to a close and the shipowners and shipbuilders are planning the postwar passenger and cargo vessels which will be plying the seas.

At this time, the experiences, both good and bad, gained during intensive wartime construction and service should be carefully evaluated in order to determine the best and most economical methods to be used for the future. The competition during this coming period will be very keen, and as a result the quality of workmanship should improve considerably and the cost should be greatly reduced.

When the war began, the tasks and quotas set for the shipbuilding industry seemed beyond realization. However, new yards sprang up all over the country, old yards expanded manyfold, and the quotas were fulfilled and surpassed. This unprecedented expansion of the shipbuilding industry, coupled with the demands of the Armed Forces, left the shipyards with inadequate supervision and a large proportion of unskilled workmen. In addition to this, the urgent demand that the ships be delivered *now*, meant that quality of workmanship was sacrificed to quantity production.

Is there any wonder, therefore, that fractures developed in some ships prior to and during service? The most dramatic example of these failures was the breaking in two of the S.S. "Schenectady."[2]

Ship Failures

An analysis of the figures presented on June 3, 1944 in the report[3] of the Board of Investigation designated by the Secretary of the Navy shows that—

From a total of 2993 ships, 95 or 3.2% developed potentially serious failures.

20 vessels or 0.67 of 1% suffered complete loss of the strength deck.

5 or 0.17 of 1% broke in two.

Cause of Failures

A report delivered before the House of Representatives[1] on June 20, 1944, reported the following:

"The causes for plate fractures may be summarized as—

1. Internal or locked-up stresses resulting from welding and the failure to observe proper welding sequence.
2. Poor quality of welding workmanship and inadequate supervision and inspection.
3. The characteristic of steel known as notch sensitivity.
4. Unity of welded structures resulting in no crack stoppers.
5. Deficiency in details of design.
6. Low temperature and temperature changes.
7. Results of ship operation practices required by the exigencies of the war.
8. Inexperienced personnel."

As a result of the foregoing, regulatory bodies required[2] that improvements be made in design and that crack arrestors, in the form of riveted gunwale bars and riveted deck straps, be added to the ships in service and the ships on the Ways.

Crack Arrestors

The above requirements sought to eliminate fractures due to design and to stop cracks once they had started. There is no doubt that this was necessary as an immediate measure to alleviate the situation. However, the blanket application of this requirement assumes that fractures are inevitable in a welded structure, and that these fractures inevitably propagate with the resultant loss of major strength members.

It seems to me that although the riveted gunwale bar could be justified for many ships built in the haste of wartime construction, it is basically unsound to insist on its use for all ships and especially for vessels built for peacetime operation under normal building conditions.

It is the contention of The Ingalls Shipbuilding Corp. that all-welded ships have, can and will be built to be completely free of fractures. The fact that 2561 of 2993 ships[3] built during adverse wartime conditions are successfully operating under severe wartime service (as of June 1944) with no indication of fracture, is ample proof of this. Also, the fact that welded hulls of the C-3 and C-1 type have developed comparatively less fractures than the Liberty ships further substantiates this thought.

As of June 1944, of 1995 Liberty Ships analyzed,[1] 9.47% developed either Class 1 or Class 2 fractures.

Of 73, C-3 Hulls, 2 or 2.74% developed these fractures.

Of 122, C-1 Hulls, 2 or 1.62% developed the same.

It is therefore obvious that a ship of superior design to the Liberty ship, despite the faults of wartime construction, has a much lower frequency of fracture.

Statistics, of course, do not show the entire picture. Therefore, let us carefully analyze the causes and see to what extent they can be controlled and eradicated.

Residual Stresses

One of the characteristics of welding is that high longitudinal stresses are developed in the weld and immedi-

* Scheduled for the Twenty-Sixth Annual Meeting, A.W.S., October 1945. Portions of this paper were delivered before the Birmingham and New Orleans Sections of the AMERICAN WELDING SOCIETY.

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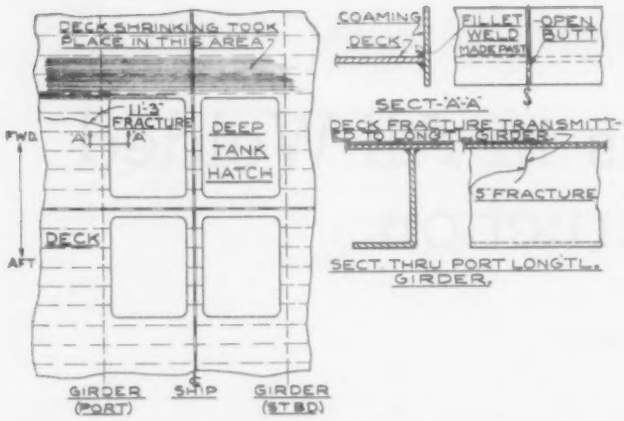

Fig. 1—Note That Excessive Flame Shrinking and 25° Change in Temperature Provided the Reaction Stresses and Energy to Propagate Fracture. A Small Crack and Sharp Notch Developed in Deck Plating When Fillet Weld Crossed the Unwelded Butt of Coaming

ately adjacent to the weld. These stresses vary with the thickness of the plate and are in the neighborhood of the yield point of the weld metal.

Considerable research has been done to determine whether the presence of these stresses reduce the strength of the welded structure.

A Committee of the Welding Research Council in a discussion[3] of the "Weld Stress Problem" states the following:

> "Experimentally it has not been shown in a laboratory that these residual stresses cause a structure to behave a great deal differently than one without them."

The above statement is limited by the following:

> - - - "practical experience indicates that this general statement cannot be carried over to thick materials where considerable triaxiality is involved. This is the object of the Structural Steel Program of the Bureau of Standards. . . ."

The results of the pilot test of Box Girder No. 1, tested at the National Bureau of Standards as part of the above program, are now available. (See Figs. 8–11.) They also indicate that the high residual stresses, deliberately welded into this 9-ton girder because of a very abusive sequence,[4] had little, if any, effect on the ultimate strength. Despite the presence of a notch, virtually the entire calculated strength was utilized before the girder failed.

Mr. Leon C. Bibber, in his paper[6] presented to the Annual Meeting of the Society of Naval Architects and Marine Engineers, comes to the following conclusion:

> ". . . good strength and elongation can be obtained from longitudinally welded joints of heavy plates in both angle type and flat plate although considerably less elongation occurs in the tee type when automatically welded with the deck in the horizontal plane."

An investigation[8] carried out under the auspices of the Ukrainian Academy of Sciences, Institute of Electric Welding, came to the following conclusion:

> "In 17 out of 19 tests which were performed, the strength of the base metal was not found to be reduced by the shrinkage stresses when the construction was subjected to static and vibration tests."

As a result of these and other investigations, there seems little doubt that residual stresses contribute little, if anything, toward reducing the strength of welded structures.

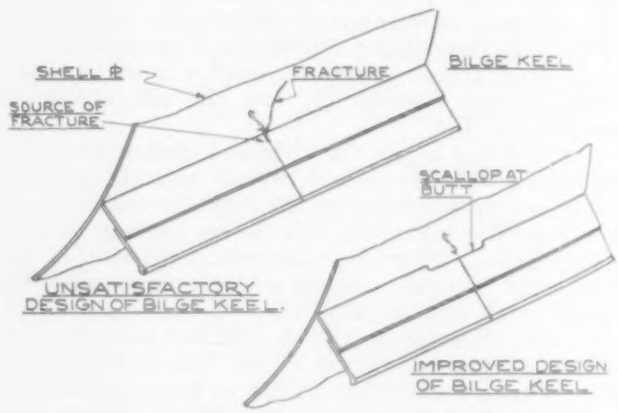

Fig. 3—Re-design and Breaking Continuity at Butt Welds, Where They Attach to Shell, Eliminates Possibility of Fracture Propagating Into Shell Plate

In addition to the above, methods have been found of reducing and controlling these residual stresses. The Low Temperature Stress Relief Method developed jointly by Sun Shipbuilding Co. and The Linde Air Products has been proved to reduce the peak values of these stresses to a very great degree. Peening the weld metal and two inches of the adjacent parent metal has also proved successful in this respect.

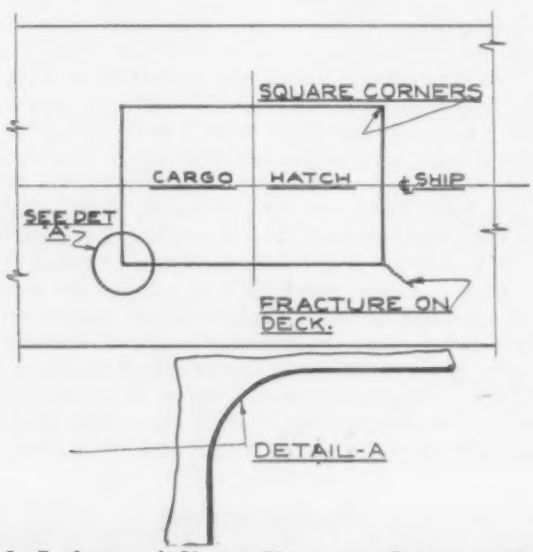

Fig. 2—Re-design of Abrupt Changes in Section at Hatch Corners, Attachments to Sheer Strake, etc., Has Already Decreased Fractures at These Locations

Reaction Stresses

Reaction stresses are those caused by the external restraint of members. If temperature changes or welding shrinkage takes place in a section under external restraint, these reaction stresses develop.

The Subcommittee on Hull Construction in its tentative report,[7] "Structural Failures in Welded Ship Construction," states:

> "If there is some focal point of high concentration of stress due to geometrical irregularities or poor workmanship, a crack is likely to start at this point and, if the reaction stresses are high enough, may extend for a considerable distance."

To cite an example from experience, which in my opinion shows the role played by reaction stresses in develop-

ing a structural failure. (See Fig. 1.) Note that here we have most of the elements of a major ship failure.

1. A completely brittle failure.
2. Comparatively low temperature, 20° to 45° F.
3. Twenty-five degrees change in temperature within 24 hr.
4. Excessive flame shrinking taking place and providing additional reaction stress and energy to propagate the fracture.
5. Disregard of good welding practice by crossing an unwelded butt in hatch coaming and developing an initial small crack and sharp notch.

Our experience shows that although reaction stresses cannot be completely eliminated, since there is always some kind of external restraint present, they can be satisfactorily controlled. This is the reason why we developed a complete and thorough fitting and welding sequence at the Ingalls Shipyard. (See paper[10] written by author in the April 1945 issue of THE WELDING JOURNAL.) A well-planned and carefully controlled fitting and welding sequence can control these reaction stresses. Special measures, including peening of close in, final welds, must be resorted to, wherever there is excessive restraint.

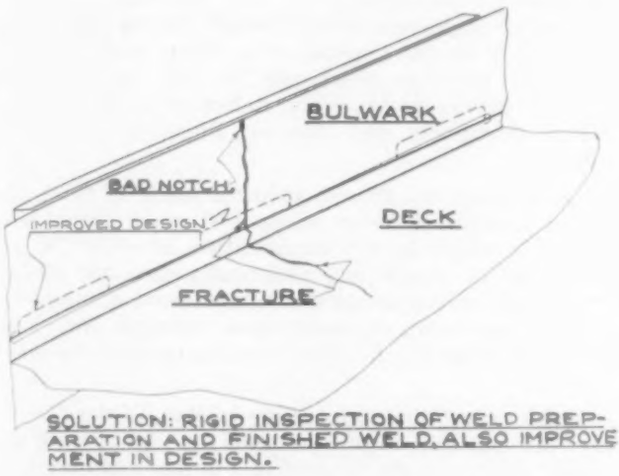

Fig. 4—Re-design and Breaking Continuity at Butt Welds, Where They Attach to Shell, Eliminates Possibility of Fracture Propagating Into Shell Plate

Stress Risers and Stress Concentrations

Stress risers are the result of abrupt changes in section in design, or notch effects which arise from defective welding, irregular burning, etc. These prevent the smooth distribution and transmission of stresses.

The Committee of the Welding Research Council in a statement[3] on "Weld Stress Problem" declares:

> "There seems to be general agreement that this one factor (stress risers) overshadows all others, and in combination with low-temperature notch sensitive steels and impact loading accounts for most of the trouble."

A careful investigation of the fractures which have occurred invariably leads us to a stress riser as the source. Since this truth stares us in the face more sharply every day, it means that the shipbuilder must pay *major attention* to eliminating these sources of fractures, if he is to produce welded ships free of failures.

A thorough analysis of past fractures, especially the more serious ones, shows that they invariably start at one of six specific locations. These locations are:

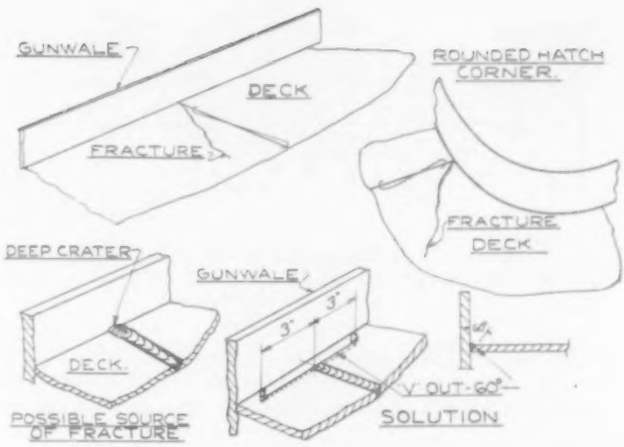

Fig. 5—Special Precautions Which Insure Sound Welding at Ends of Erection Butts in Main Deck, Eliminates These Locations as Crack Starters

1. Square hatch corners.
2. Notch or abrupt change in section at the upper edge of the sheer strake.
3. Faulty weld at gunwale connection.
4. Faulty weld at end of Main Deck erection butts.
5. Faulty weld at bulwark and continuity at bulwark butts to main structure.
6. Faulty weld in bilge keel and continuity at bilge keel butts to bilge strake.

It is obvious therefore that each individual fracture has as its starting point a stress riser in the form of poor design or faulty workmanship. As a result of requirements[2] on the part of regulatory bodies, most of the design stress risers at the above crucial locations have been eliminated. The hatch corners have been reinforced and rounded. (See Fig. 2.) The attachments at the sheer strake have been either eliminated or redesigned to allow for a smooth transmission of stresses. The bilge keel and bulwarks have been improved and no longer allow continuity in way of welded butt joints. (See Figs. 3 and 4.)

The above-cited measures alone have reduced the fractures in these locations to a very great extent. More steps can and are being taken to further improve the design of our ships. In order to guarantee that no detail of design is overlooked, the Ingalls Shipbuilding Corp. is carefully reviewing all plans and is making alterations where they are justified.

Workmanship

Given a satisfactory design, the most crucial factor in building ships which will be free of fractures, is painstaking workmanship. Although it is understandable, it is quite unfortunate that this was lost sight of, to some extent, during the intense effort to fulfill the demands

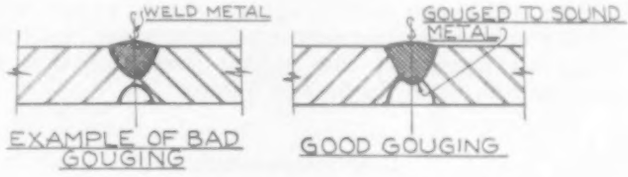

Fig. 6—Careful Back Gouging Eliminates Cracks from Forming in Welds

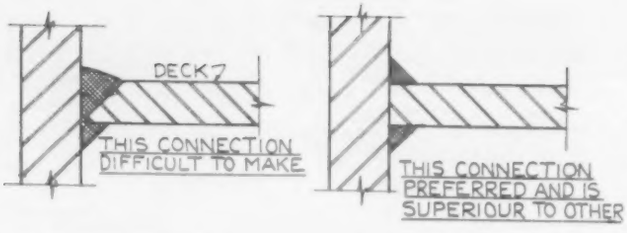

Fig. 7—A Good Full Penetration Weld, with Only One Side Beveled, Is Difficult to Deposit. Double Fillet Weld Is Preferable at Gunwale Connection

of the shipbuilding program. The Ingalls Shipbuilding Corp. is rather proud that it laid major emphasis on good workmanship all the way through this emergency program.

The problem of building fine all-welded ships is not something which can be discussed and resolved in the abstract. These vessels must be built by a designated number of men. If they do not understand the nature of welding and if they do not intelligently use their tools, the product will be inferior.

There has been a tendency on the part of some people to say that a ship is so large and there is so much welding on it that it is impossible to ensure that all the welding is sound. The fractures which tend to endanger the 100% welded ship are not located all over the ship. They are localized to six specific locations. When the problem is approached from this point of view, it is not overwhelming. It therefore becomes a relatively simple, but very important, job to guarantee the quality of work at these points.

There are no deep dark secrets about these danger areas; therefore, the builder must make arrangements to take special precautions at these locations.

Careful preparation and welding are required at each erection joint of the Main Deck. The starting and ending points of these welds should be cleaned out in way of the welding to the shell and hatch coamings and rewelded. (See Fig. 5.) These welds should be peened in order to minimize root cracks. Back gouging should be carefully carried to sound metal. (See Fig. 6.) If the above precautions are followed there is little likelihood of stress risers due to faulty welds.

The upper edge of the sheer strake has already been cleared of abrupt changes in design. It will therefore be a comparatively small job to inspect the same for notches caused by careless burning, etc.

The gunwale connection itself should be redesigned from a full penetration weld to a double fillet. It is much more simple to deposit a sound fillet weld than try to make a good connection out of a badly designed joint. (See Fig. 7.) All Ingalls vessels have this double fillet at their gunwale connection, and in no case has this been a source of fracture.

The bilge keel and bulwark butts can be carefully prepared and welded. There are not too many of these to make the job complicated. Already the discontinuity in present design allows a considerable safety factor.

It is therefore fairly evident that these special measures at a limited number of important locations are entirely in order and surely justify the full attention of the builder. Although these safeguards should be part of the regular production process, rigid inspection, including X-ray, if necessary, can further guarantee that the workmanship is on the highest quality.

Low Temperature

At comparatively low temperatures, ship steel develops high notch sensitivity. This characteristic of steel contributes to failures in the presence of a sharp notch. It therefore follows that either the notches must be eliminated or a steel must be found which has low notch sensitivity at low temperatures. Such a steel has already been suggested, with low carbon, high manganese and some aluminum.

It should be kept in mind that notches in design or workmanship are still undesirable even for a steel of low notch sensitivity. Therefore, we again end up with the need to eliminate stress risers and stress concentrations. It is my opinion that these have and can be eliminated where proper control has been exercised.

It ought to be mentioned at this time that investigations have shown that the notch sensitivity of the weld metal is not greater than that of the base metal. It is a rather common observation that those fractures that do start in the weld invariably tend to propagate in the adjacent parent metal.

Another important point, I would like to call attention to, is that in the absence of a sharp notch, a welded structure develops practically its full strength. Mr. Leon C. Bibber, in his paper[8] delivered to the Society of Naval Architects and Marine Engineers, states the following:

> "It is seen that these specimens made of thick plate and containing these residual stresses, when tested at the relatively low temperature of +20° F. were capable of developing practically the full ultimate strength and elongation attained from a virgin base metal specimen, certainly more strength and elongation than the joint could be called upon to develop in a ship."

I also expect that the testing of Box Girder No. 2 at the National Bureau of Standards at −40° F. will show similar results, in the absence of a notch, and despite the presence of multi-directional constraint.

Rigidity

In examining the fractures which have occurred, the fact that the failures were brittle in character and that no or little plastic flow took place, stands out. To a certain extent this is attributed to the presence of multi-directional constraint characteristic of a ships's design. Again referring to the test of Box Girder No. 1, at the National Bureau of Standards, we see that despite the severe constraint, the brittle fracture and the maximum of 2.1% reduction in thickness at the fracture, the girder did not fail until practically its entire strength was utilized. (See Figs. 8–11.) This failure took place after about 8-in. deflection from the neutral axis, and about 6-in. permanent "set."

It does not seem, therefore, that the great rigidity of this 9-ton girder, built from $2^1/_2$-in. and $1^1/_2$-in. plate,

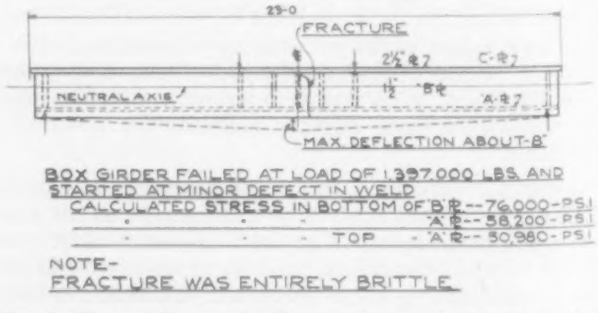
23-0
FRACTURE
NEUTRAL AXIS
MAX DEFLECTION ABOUT-8"
BOX GIRDER FAILED AT LOAD OF 1,397,000 LBS AND STARTED AT MINOR DEFECT IN WELD
CALCULATED STRESS IN BOTTOM OF B & C -- 76,000-PSI
A -- 58,200-PSI
TOP A -- 50,980-PSI
NOTE-
FRACTURE WAS ENTIRELY BRITTLE

Fig. 8—Data on Box Girder No. 1. Practically Full Strength of Girder Utilized Before Fracture Occurred

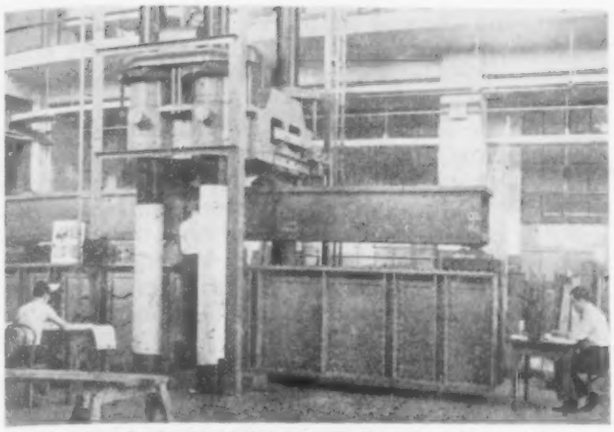

Fig. 9—Box Girder No. 1 Ready to Be Tested at National Bureau of Standards, Wash., D. C. Box Girder No. 1 Was Built at Ingalls Shipbuilding Corp. Five More Will Be Built as Part of the Same Program

decreased the over-all strength under a test of static loading. There is no doubt that the design did contribute toward developing a brittle type of failure.

If this test can be taken for an indication, it seems to me that the rigidity or multi-directional constraint existent in welded ships does not reduce their ultimate strength and therefore make them more susceptible to failure. We do know that the normal "working," hogging and sagging, of the all-welded ship is not hampered by its welded joints.

There is no question that much more can be done to further investigate this problem.

Absence of Crack Stoppers in All-Welded Ships

It is true that all-welded ships today do not have crack stoppers. However, given a ship which has been carefully constructed, it is the contention of the Ingalls Shipbuilding Corp. that this requirement is unnecessary. We feel that the real problem is to stop the crack from starting. If all hands concentrate on improving design and achieving superior workmanship, the theory of supplying crack stoppers becomes superfluous.

Fig. 10—Detail of Fracture After Completion of Test, Box Girder No. 1

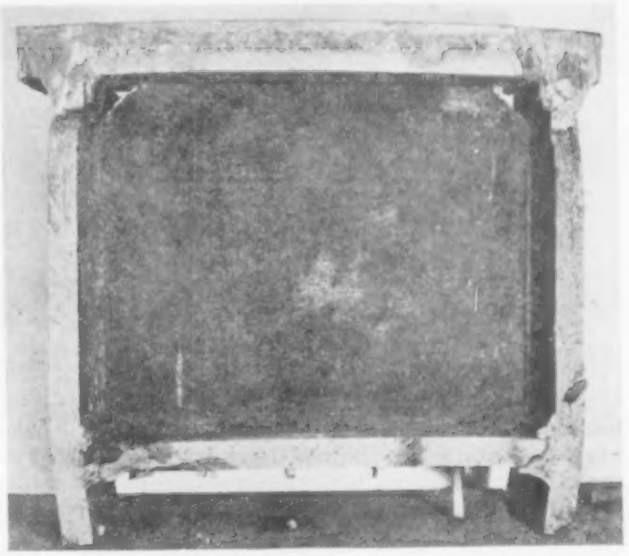

Fig. 11—Cross-sectional View Showing Brittle Fracture. Note Defect in Weld at Lower Left Hand

Despite the foregoing, future tests have been planned to investigate the possibilities of developing a welded type of crack stopper. These tests are part of the program[4] conducted at the National Bureau of Standards. (See Fig. 12.)

We should also keep in mind that despite the low notch toughness of ship steel, a very low proportion of ship fractures have propagated from one strength member to another.

Wartime Operating Conditions

The abuse taken by our ships during the war, such as overloading, pushing full speed ahead in bad weather to maintain position in a convoy, etc., has been listed as a contributing factor in developing fractures. There is no reason to believe that private owners will mistreat their ships in this manner after the war.

S.S. "Sea Porpoise"

A good deal of attention has been paid to the fractures which have developed and in a sense this is good because it has laid the preconditions for eliminating the causes. However, comparatively little has been said of the terrific punishment taken by some of the all-welded ships. Statistics do show that of the all-welded ships built, 85.6% have developed no sign of fracture as of June 1944, despite the shortcomings of wartime shipbuilding and ship operation.

At this point, I would like to call attention to a ship, S.S. "Sea Porpoise," built by Ingalls as a C3-S-A2 vessel, and converted to an Army transport. This ship

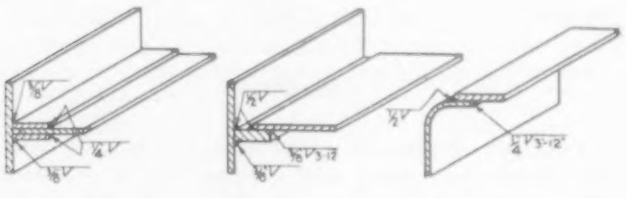

Fig. 12—Typical Designs for Crack Stoppers. These Will Be Tested as Part of Program at National Bureau of Standards

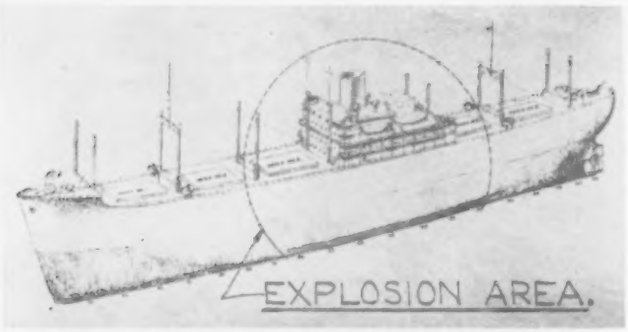

Fig. 13—Artist's Sketch Showing Explosion Area of "Sea Porpoise"

underwent an experience, the survival of which I believe can be attributed to the fact that it was of welded construction. A severe underwater explosion took place beneath the bottom at midships, causing a tremendous upward pressure, bodily lifting the vessel from 2 to 3 ft., according to Lieutenant Commander E. V. Williams, then first mate and now master of the vessel.

Although buckling took place on the shell between two frames on the starboard side, extending from the flat keel to the sheer strake, not a single leak developed in the weld or plating. A small leak did finally develop in the flat bottom at the longitudinal girder in the cofferdam when the ship was lifted out of the water in drydock. As a result of the explosion, the severe hogging action did develop three small fractures in the shelter deck at three square hatch corners. Other structural, piping and machinery damage was sustained below the shelter deck, but these did not affect the basic hull structure. No damage was found at the gunwale connection. (See Figs. 13–15.)

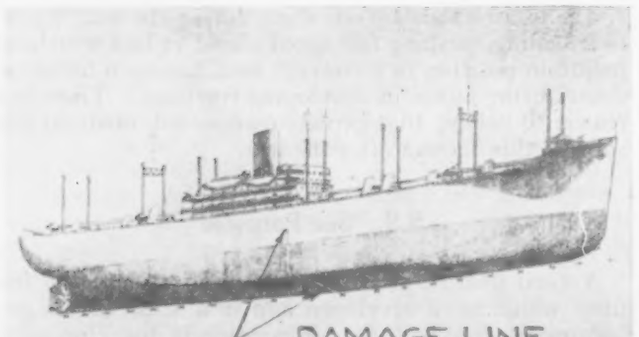

Fig. 14—Artist's Sketch Showing Shell Damage Line of "Sea Porpoise"

The terrific punishment taken by this ship is surely a testimony to all-welded ship construction. It is also high praise for the work done at Ingalls, for not a single weld installed by the Ingalls Shipyard during the original construction of the ship showed a sign of failure. Keeping this in mind, and with our present improved design, it would surely be a step backwards to require a riveted gunwale bar on this type of ship.

Conclusion

I am not offering this paper with the thought that the last words have been said concerning the building of 100% welded ships. There are still many problems to be solved, and there is much research work to be done. However, it is my firm belief that the theory of completely welding large structures such as ships, should not be discarded at this time.

Peacetime standards and highly skilled workmen will remain in the shipyards which will continue operating. Added to this, careful planning and adequate supervision will undoubtedly allow us to overcome the faults of hasty wartime construction. We have and will continue to build cheaper, faster and stronger welded ships.

I would like to conclude with some pertinent remarks made by the Subcommittee on Hull Construction in its report[7] on structural failures:

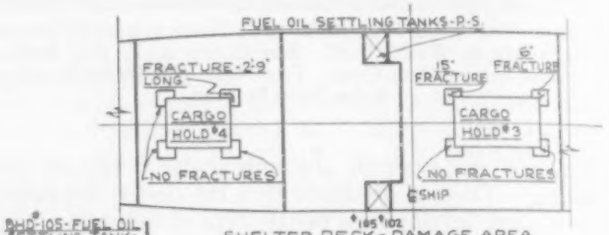

Fig. 15—Details Showing Fractures Developed as a Result of Explosion

"Probably the greatest source of trouble under present conditions is overconfidence on the part of production workers and supervision who have violated rules of procedure in the past without apparent trouble and who fail to realize that the margin of safety may be entirely destroyed by a combination of circumstances in another case.

"Properly informed and adequate supervision, not only in welding but in the departments preparing the materials for welding, is a necessary factor in engineering control."

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Chemical Factors Affecting the Welding Properties of Stabilized 18–8 Stainless Steel*

By Franklin H. Page, Jr.†

IN THE oxyacetylene and atomic hydrogen welding of 18–8 stainless steel one hears the frequent complaint from welders and their foremen that some heats of steel are much more difficult to weld than others. In the manufacture of products such as aircraft exhaust manifolds, where oxyacetylene welding represents a very large portion of the total manufacturing cost, losses due to poor welding properties of some heats of steel may become quite expensive.

A company laboratory, such as the author's, which is in the habit of going through the routine of checking on materials for compliance with the government specifications, easily drifts into the habit of discounting these complaints after it has been demonstrated that the material in question complies with the Army-Navy specifications. However, it was repeatedly demonstrated by our welders that some lots of stabilized stainless steel could be welded at speeds more than three times as fast as the maximum welding speed for another lot of the same type of stainless steel.

As it would be of considerable value to any fabricator to be able to obtain stainless steels all heats of which had as good welding properties as the best heats heretofore seen in the shop, an attempt to correlate these welding properties with chemical composition and any other controllable factors was indicated.

In the investigations which followed, 208 heats of Type 321 titanium-stabilized stainless steel and 36 heats of Type 347 columbium-stabilized stainless steel were rated as to their relative weldability and these results correlated against the chemical composition and other data. The results of this investigation indicate that the cost of welding stabilized stainless steels using oxyacetylene or atomic hydrogen may be materially decreased by slight changes in the chemical composition within existing specifications.

Weldability Index Scale

It is admitted that the application of the term "weldability" to austenitic stainless steels which show no quench hardening is not in accordance with the most widely used sense of this term. However, no other term seems to describe adequately the property in question.

In order to have a scale for judgment of the relative speeds with which various stabilized stainless steels may be welded a numerical index scale has been established rating the weldability of these steels from 0 to 5. A separate evaluation must be made for each type of welding and it is quite possible that one steel might have a number of weldability indices: for instance, a weldability index of 3 with oxyacetylene welding, a weldability index of 2 with atomic hydrogen welding and a weldability index of 5 with helium or argon shielded arc welding. The weldability index may also vary with the type of flux used on fluxed seams.

It is understood that the maximum speed at which welding can be done depends upon torch adjustment and the skill of the operator, as well as the chemical composition and the preparation of the joint. The weldability tests in the case of oxyacetylene welding were performed with a neutral or very slightly reducing flame and with the optimum amount of heat input for the particular speed at which the metal was being checked. Clean, scale-free material was used and all other welding conditions, such as the height of the flame above the metal, were those generally considered to be the best practices. In general, weldability is rated on the basis of the net production per 8-hr. day by a welder of better than average ability with the usual utilization of his time.

A weldability index of 0 indicates a stainless steel which is impractical to weld at any speed: it shows crow's-feet and porosity such as pinholes and wormholes at the lowest speed at which the fire is hot enough to melt the metal.

Weldability Index of 1.—Weldable only at *very* slow speeds. The average production welder can achieve about 400 in. per day (on a butt weld with 0.050-in. material) without very much difficulty on this material. An unusually skillful welder could net 600 in. per day, but with considerable difficulty and much hard work in that he would have to stir out unusually great quantities of gas. Even with the most skillful welder, pinholes and crow's-feet would result from a 600-in.-per-day speed.

Weldability Index of 2.—Approximately equivalent to the average Type 321 stainless steel currently available. The average welder could be expected to net about 600 to 700 in. per day, though with much hard work he might produce 800 in. with a considerable amount of porosity and pinholes. A good welder with very hard work could produce approximately 1000 in. per day though with quite a bit of trouble from crow's-feet and pinholes.

Weldability Index of 3.—The average welder can produce from 800 to 1000 in. per day without much difficulty and a good welder can produce 1200 in. per day or better, with no crow's-feet or pinholes.

Weldability Index of 4.—A good welder can make about 1400 in. per day with no trouble at all and no pinholes or other porosity. The average welder could net 1000 to 1200 in. per day if supervision were to speed him up and if all steel used rated 4 or better, so that he would get into the habit of welding at this speed.

* Scheduled for the Twenty-sixth Annual Meeting, A.W.S., October 1945.
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Table 1—Composition Correlation Groups. AISI Type 321 (18–8-Titanium) Stainless Steel

	Group I	Group II	Group III	Group IV	Group V
Ti	0 - 0.41	0.42 - 0.46	0.47 - 0.58	0.59 - 0.66	0.67 -up
C	0 - 0.052	0.053 - 0.062	0.063 - 0.081	0.082- 0.092	0.093- 0.10
Mn	0.20- 1.18	1.19 - 1.26	1.27 - 1.39	1.40 - 1.55	1.55 - 2.50
P	0 - 0.013	0.014 - 0.017	0.018 - 0.025	0.026- 0.031	0.032-0.040
S	0 - 0.0054	0.0055- 0.0086	0.0087- 0.0169	0.017- 0.0199	0.020-0.040
Si	0.20- 0.33	0.34 - 0.41	0.42 - 0.56	0.57 - 0.70	0.71 -1.50
Ni	7.00- 9.80	9.81 -10.18	10.19 -10.47	10.48 -10.79	10.80 -up
Cr	17.00-17.27	17.28 -17.61	17.62 -17.97	17.98 -18.41	18.42 -up
Al	0 - 0.08	0.09 - 0.14	0.15 - 0.17	0.18 - 0.22	0.23 -up
Ti/C	4.00-6.0	6.1 - 7.2	7.3 - 8.6	8.8 -10.0	10.1 -up
Cr/Ni	0 - 1.71	1.72 - 1.77	1.78 - 1.91	1.92 - 2.03	2.04 -up

Weldability Index of 5.—This weldability rating is the present goal in improving the weldability of sheet stainless steel and is limited only by the ability of the welder to move along on the particular thickness on which he is working. A welder of unusual skill could produce 1600 in. per day without much difficulty. The average welder of limited experience could produce 1600 in. per day if supervision were to teach him to move at this speed and if he always had steel with a weldability index of 5 so that he could develop the habit of moving at this speed.

We have found it most useful to evaluate the steels by having them welded by one or more skilled operators of supervisory grade who are familiar with production-welding problems and are able to estimate how much production a welder could turn out with a particular set of welding conditions. They are instructed not to attempt to assign fractional index numbers but the nearest full number. It is admitted that this is a quite subjective way of judging welding performance but it is demonstrated that the weldability numbers assigned by the various operators trained in this work correlate with each other.

Chemical Correlation Groups

For the purpose of correlating chemical composition and weldability, a statistical analysis of the distribution of percentages of each element and of certain element ratios was made on several hundred heats each of Type 321 and Type 347 stainless steel. On the basis of these statistical analyses five correlation groups were set up for each element and element ratio in each of the two types of stabilized stainless steel.

Ten per cent of the samples are in Group I, representing the smallest amount of the element; 25% of the samples are in Group II, representing the next larger amount of the element; 30% in Group III, in the middle of the range; 25% in Group IV, next greater than Group III; and 10% in Group V, the samples containing the largest amount of the particular element. The limits of these groups, in terms of the element content in the samples, are shown in Tables 1 and 2.

As an example of the application of these correlation groups we can assume a hypothetical stainless steel heat containing 0.078% carbon, therefore being in carbon correlation Group III; containing 0.018% sulfur, correlation Group IV; 0.026% phosphorus, correlation Group IV; 0.36% silicon, correlation Group II; 1.29% manganese, correlation Group III; 18.31% chromium, correlation Group V; 9.90% nickel, correlation Group II; 0.44% titanium, correlation Group II; with a titanium-to-carbon ratio of 5.55, therefore in the titanium-carbon Group I; with a chromium-nickel ratio 1.85, Group III.

Weldability Indices and Their Correlation

Weldability indices for oxyacetylene welding were assigned to 208 heats of Type 321 titanium-stabilized stainless steel and 36 heats of Type 347 columbium-stabilized stainless steel. Flange-edged type preparation was used on these specimens in order that the welds could be made without dilution of the weld metal by addition of filler rod. This method is frequently used on the production welding of stainless-steel stampings. In this method a flange approximately $^1/_{16}$ in. high is turned up on the edge of the specimen and is melted down in the welding operation. The metal was fluxed with Solar Type 16GH welding flux. It was demonstrated that the type of flux used has a considerable effect on the speed at which the material could be welded and therefore on the weldability index. This flux was standardized so as to have all results comparable.

The weldability of a smaller number of specimens was determined using atomic hydrogen and argon shielded gas welding. The results with oxyacetylene were correlated with the various element groups by averaging the weldability numbers of all samples falling within each element correlation group. These results are tabulated in Tables 3 and 4. The reason for including the stabilizing element-to-carbon ratio, and the chromium-to-nickel ratio, is that these ratios are suspected of having an effect upon the forming properties of stainless-steel sheet and sometime possibly may be specified.

An additional correlation was made with the manu-

Table 2—Composition Correlation Groups. AISI Type 347(18–8-Columbium) Stainless Steel

	Group I	Group II	Group III	Group IV	Group V
Cb	0 - 0.65	0.66 - 0.78	0.79 - 0.94	0.95 - 1.08	1.09 -up
C	0 - 0.047	0.048 - 0.058	0.059 - 0.077	0.078 - 0.094	0.095-0.10
Mn	0.20- 1.18	1.19 - 1.32	1.33 - 1.67	1.68 - 1.86	1.87 -2.50
P	0 - 0.012	0.013 - 0.017	0.018 - 0.024	0.025 - 0.031	0.032-0.040
S	0 - 0.0057	0.0058- 0.0086	0.0087- 0.0136	0.0137- 0.0189	0.019-0.040
Si	0.20- 0.27	0.28 - 0.40	0.41 - 0.54	0.55 - 0.64	0.65 -1.50
Ni	7.00- 9.97	9.98 -10.70	10.71 -11.19	11.20 -11.49	11.50 -up
Cr	17.00-17.38	17.39 -17.69	17.70 -17.99	18.00 -18.51	18.52 -up
Cb/C	8.00- 9.8	9.9 -10.8	10.9 -12.8	12.9 -14.3	14.4 -up
Cr/Ni	0 - 1.55	1.56 - 1.65	1.66 - 1.72	1.73 - 1.91	1.92 -up

facturers of the steel. These data are tabulated in Tables 5 and 6. (The manufacturers are identified by code letter only as it is not the policy of the author's employer to reveal the identification of these manufacturers to anyone other than a representative of the particular company concerned.) The manufacturers represented here melt and roll most of the tonnage of stainless-steel sheet produced in the United States. Further examination of the differences in weldability of stainless steel furnished by various manufacturers demonstrated that these differences were due only to the ranges of the silicon and manganese content which they habitually provided in their products, although all materials checked complied with Army-Navy Aeronautical Specification AN-QQ-S-757. The higher silicon and higher manganese products of manufacturers C and E were equal to any material produced by manufacturers A and G.

Table 3—Correlation of Average Weldability Indices with Composition Groups. Type 321 (18–8-Titanium) Stainless Steel. Oxyacetylene Welding, Solar 16GH Flux

(Figures tabulated are the average weldabilities obtained on samples for this group.)

	Group I	Group II	Group III	Group IV	Group V
Ti	1.57	1.44	1.66	1.82	*
C	1.44	1.73	1.62	2.06	*
Mn	1.84	1.58	1.61	1.56	2.53
P	*	1.86	1.60	1.79	*
S	*	1.60	1.55	*	*
Si	0.75	1.10	1.61	2.50	2.54
Ni	1.74	1.52	1.56	1.94	*
Cr	*	1.53	1.89	1.42	1.80
Al	1.83	1.60	1.94	1.60	1.75
Ti/C	1.40	1.41	1.67	1.69	1.54
Cr/Ni	1.84	1.61	1.51	1.70	*

* Too few samples of this group were taken to present a valid correlation.

Table 4—Correlation of Average Weldability Indices with Composition Groups. Type 347 (18–8-Columbium) Stainless Steel. Oxyacetylene Welding, Solar 16GH Flux

(Figures tabulated are the average weldabilities obtained on samples for this group.)

	Group I	Group II	Group III	Group IV	Group V
Cb	*	1.83	1.58	2.00	*
C	*	1.57	2.00	*	*
Mn	*	*	2.00	*	*
P	*	1.75	1.40	*	*
S	*	*	1.64	*	*
Si	1.00	1.29	1.71	2.00	3.00
Ni	2.67	1.75	1.50	*	*
Cr	*	*	1.40	1.85	2.13
Cb/C	2.25	2.00	1.80	1.80	1.50
Cr/Ni	1.33	1.37	2.00	2.00	*

* Too few samples of this group were taken to present a valid correlation.

It will be noted on examination of the data in Tables 3 and 4 that the most important element as far as effect upon weldability is concerned is silicon. Manganese and titanium seem to have a lesser effect and the other elements practically no effect at all in their usual ranges. As a means for improving the welding properties of stabilized stainless-steel sheet we have informed our sources of steel that we intend to specify a minimum silicon content of 0.50% in the near future and possibly minimums of 0.60% silicon and 1.25% manganese, the composition of the steel to remain within the limits specified by Army-Navy Aeronautical Specification AN-QQ-S-757.

Table 5—Correlation of Steel Manufacturer with Weldability of Type 321 (18–8-Titanium) Stainless Steel

Manufacturer (Code Letter)	Average Weldability of Manufacturer's Product
A	2.30
B	Not enough samples for valid average
C	1.65
D	Not enough samples for valid average
E	1.14
F	Not enough samples for valid average
G	2.46

Table 6—Correlation of Steel Manufacturer with Weldability of Type 347 (18–8-Columbium) Stainless Steel

Manufacturer (Code Letter)	Average Weldability of Manufacturer's Product
A	Not enough samples for valid average
B	Not enough samples for valid average
C	2.25
D	Not enough samples for valid average
E	1.33
F	Not enough samples for valid average
G	Not enough samples for valid average

Probably more important than obtaining an increase in the average weldability index of all stainless steels available is the decrease in the percentage of those steels showing a weldability of 1 or below. A welder of average skill has a tendency to develop the habit of welding at the production rate available with the slowest steel which he is likely to encounter. It is, therefore, more important that the slowest steel which he is likely to encounter have as fast a welding rate as possible, rather than to have the average raised by a few steels of exceptional weldability. Table 7 shows the expected weldability with the specifications which are suggested above. It is noted that the increase in the weldability index is significant and that the final specification suggested will eliminate all but a very small proportion of the samples with low weldability, allowing the welders to develop a habit of moving at a considerably more rapid rate.

That this specification is practical is shown by a survey which indicated that 23% of all titanium-stabilized stainless steel now being melted has 0.60% or more silicon and 1.25% or more manganese. An investigation in our plant seems to indicate that putting these limits on silicon and manganese will not affect the forming properties of the steel.

Effect of Silicon and Manganese

The primary difficulty with those heats of stainless

Table 7—Probable Improvement of Weldability Index with Suggested Specification Changes. Type 321 (18–8-Titanium) Stabilized Stainless Steel. Oxyacetylene Welding, Solar 16GH Flux

(All Type 321 to conform to AN-QQ-S-757, Army-Navy Aeronautical Specification, in addition to requirements of this table.)

Suggested Specification Minimums	Average Weldability Index	% of Samples Meeting Specification	% of Heats Meeting Specification Which Have Weldability Indexes of 1 or 0
As now furnished	1.63	100	44
0.50% Si	2.35	51	18
0.60% Si	2.3	32	10
0.60% Si } 1.25% Mn }	2.3	23	5

steel which show poor weldability is the evolution of gas on the cooling side of the weld puddle. This gas seems to be evolved either at the moment of solidification or immediately preceding it. The amount of gas evolved and the ease with which it is eliminated from the steel seem to be the controlling factors in limiting the speed at which the material may be welded in production. It is assumed for the purpose of this paper that any gas porosity represents an unacceptable defect and that the finished weld must be free of wormholes and pinholes. The weldability index number is based upon the limiting speed at which this material may be welded with optimum torch adjustment without obtaining any gas porosity, by certified aircraft welders with approximately three years' experience of welding stainless steel.

The ease with which the gas is evolved depends upon the nature of the slag on top of the puddle. In the case of some samples which formed a very heavy slag the gas was evolved relatively easily and with other samples which had a very thin slag the gas got through only with difficulty. It is believed that possibly part of the beneficial effect of manganese is an alteration in the form of the slag to enable the gas to be more readily eliminated.

No attempt has been made by the author of this paper to analyze the minute quantity of gases which the solidifying metal gives off. It is thought that their behavior may be due partially to the solubility of hydrogen in the liquid metal, hydrogen in its most active form being available in the inner portions of the oxyacetylene flame and also in the atomic hydrogen welding arc. However, it is assumed that the major source of this gas is the evolution of carbon monoxide from the reaction of metallic oxides with carbides in the metal. Metallic oxides are formed in the welding operation from oxidation ahead of the torch or may be introduced from sloppily made tack welds or from the oxidizing zones of the flame. Excessive gas trouble may be encountered if the hot filler rod is taken out of the protective flame and allowed to be oxidized by the air and then applied to the weld. It is assumed that the extreme effectiveness of silicon in decreasing the amount of gas trouble encountered may be due to its action as a de-oxidizer and slagging element and preventing these oxides from reacting with carbon to form carbon monoxide. A recent article by Morton C. Smith of the Department of Metallurgy of Montana School of Mines, "Gas Evolution in Arc Welding Steels and Its Effects Upon the Welding Process," in THE WELDING JOURNAL, **24** (4), Research Suppl., 226-s (April 1945), clearly describes the reactions which produce carbon monoxide in welding operations.

A small number of samples of both Type 321 and Type 347 stainless steel were welded using the atomic hydrogen welding process. The number of samples was too small for presentation of the same type of correlations shown for oxyacetylene welding. However, they clearly indicate that a minimum of 0.50% silicon is necessary for satisfactory welding properties.

Another group of samples was tested for the effect of composition on helium and argon shielded arc welding.

Table 8—Probable Improvement of Weldability Index with Suggested Specification Changes. Type 347 (18-8-Columbium) Stabilized Stainless Steel. Oxyacetylene Welding, Solar 16GH Flux

(All Type 347 to conform to AN-QQ-S-757, Army-Navy Aeronautical Specification, in addition to requirements of this table.)

Suggested Specification Minimums	Average Weldability Index	% of Samples Meeting Specification	% of Heats Meeting Specification Which Have Weldability Indexes of 1 or 0
As now furnished	1.86	100	35
0.50% Si	2.43	35	*
0.60% Si	*	*	*
0.60% Si } 1.25% Mn }	*	*	*

* Not enough samples for valid average.

Very little or no correlation was found between welding properties and variations in the chemical content within the specification limits. There was one exception: where burned tack welds existed, it was found that they could be picked up much more easily on the samples containing 0.50% silicon or more.

Quite naturally, some welders who have experience with welding only one of the two types of stabilized stainless steel are strongly prejudiced in favor of the type they are accustomed to using. A contributing factor may be that slight differences in flame adjustment produce unlike results in making welds on the two types of material. For instance, the use of a little too much excess acetylene (a common production welder's practice requiring careful instruction and frequent checkup by supervision) will result in the loss of some of the stabilizing effect due to carbon picked up from the excess acetylene.

In welding columbium-stabilized material, this excess acetylene does slightly decrease the amount of gas evolved and, therefore, it is a very natural error on the part of the welder. However, in welding titanium-stabilized material the same slight excess of acetylene causes an increase in the amount of gas encountered. Titanium stainless may be welded without too much difficulty using a very slight excess of oxygen although this is not good practice as it may result in loss of some of the titanium; however, it will be almost impossible to make a good weld on columbium stainless using the same slight excess of oxygen.

Both materials may be welded without carbon pickup and without loss of the stabilizing element using an exactly neutral flame or one carrying such a slight excess of acetylene that the "feather" or intermediate flame cone is between $^1/_{32}$ in. and $^1/_{16}$ in. long. If the silicon and manganese content are as suggested in this paper, there is very little to choose between the two types of steel with respect to welding properties.

Resistance Welding for Economy and Quality

By Lester A. McIntosh*

THE problem here discussed arose through the necessity of reducing cost and increasing the strength of the front axle support for Ford-Ferguson farm tractors.

At the left in Fig. 1 is a photograph of a malleable iron casting with an assembled arc-welded steel stamping. This assembly was formerly used as the front axle support and radiator support of the Ford-Ferguson farm tractor. With the ever present demand for increased strength and rigidity, coupled with the effort to reduce production costs, several designs of arc-welded and riveted assemblies were submitted for engineering tests for comparison with the cast malleable iron and arc-welded assembly shown.

After several months of development and testing, only one of the many submitted designs compared favorably with the original casting on economy and quality. This new design shown in Fig. 2 proved to be a riveted assembly of the rear portion of the support which was made from $^1/_4$-in. thick steel and the front portion of the support made from $^3/_{16}$-in. thick steel requiring eight $^1/_2$-in. diameter steel rivets. The front and also the rear portions of this support were each in turn reinforced with a $^1/_2$-in. steel plate at the axle pivot pin to give a greater area of bearing at this vital point. These two reinforcements each required three $^1/_2$-in. diameter rivets thus making a total of 14 rivets in the completed assembly.

Results of actual breakdown tests on this riveted design showed a possible weakness in the $^1/_4$-in. rear stamping. The upper, open end of this stamping deformed under severe overload and allowed the bolting flange to deflect from its original plane surface. In designing this stamping, the large opening was incorporated to give maximum fan belt clearance to crank shaft fan pulley which is completely protected and covered by the lower end of the stamping. The tests also revealed that the two ears turned outward from the surface for riveting to the $^3/_{16}$-in. thick stamping (compare with Fig. 3) were not stiff enough to withstand the dynamic loads encountered as the axle turned about the center pivot point from the limiting flange on one side of the $^3/_{16}$-in. thick stamping to the limiting flange on the other side. In redesigning the stamping made from $^1/_4$-in. steel, a $^1/_2$-in. high flange was added across the open end and the two ears were eliminated and the respective rivets located as high up in the corner under each axle limiting flange as possible, while an additional two rivets were added in the lower flanges of the large stampings. The total rivets then required increased to sixteen.

In estimating the tooling cost to produce this approved stamping assembly, it was found that no fewer than four piercing operations were practical to perforate the four stampings which required 32 holes for the 16 rivets and none of these four operations could be incorporated in other operations required for the normal production of the four stampings up to the stage of preparation for riveting. The cost of these tools plus the production labor required for the four operations gave rise to the question of the advisability of an assembly by resistance welding.

Following this line of thought of resistance welding, a new tooling cost estimate was made. By coining three $^1/_2$-in. diameter projections on each of the two $^1/_2$-in. steel reinforcing plates in the same die that strikes these plates flat and rounds the edges to provide proper nesting into the recess in each of the large stampings, and coining four projections on the surface of the rear support in the same die that restrikes this part for controlling dimensions, no additional dies or stamping operations are re-

* McIntosh Stamping Corp., Detroit, Mich.

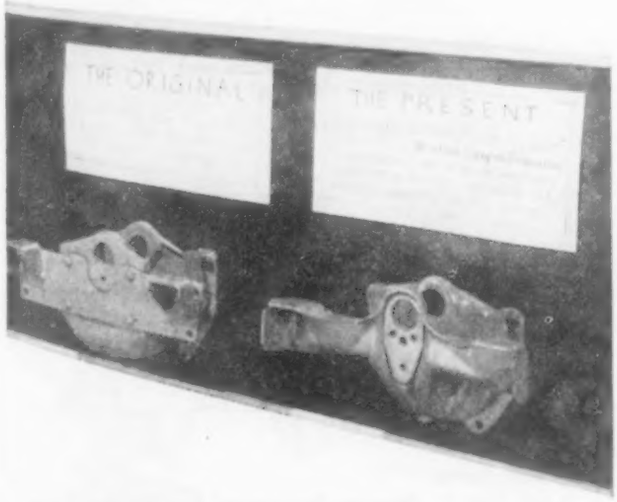


Fig. 1—Malleable Iron Casting at Left and Steel Stamping Assembly Resistance Welded

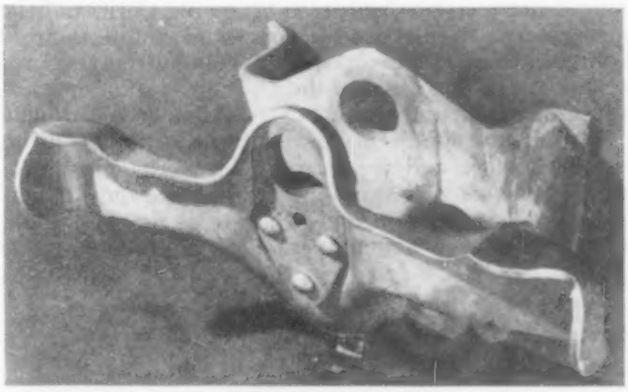


Fig. 2—Riveted Steel Stamping Requiring 14 Rivets

quired, provided the six remaining points of fusion are effected by spot welding, namely, the two on either side and the two on the bottom of the large stampings. This method of procedure eliminates the necessity of any preparation for assembly performed on the large $^3/_{16}$-in. thick stamping and consequently, a lesser amount of handling in the stamping operations producing this part.

The success of any product similar to the one discussed in this paper is partially dependent upon uniform and accurate assembly work. This is somewhat effected by designing the dies which are to produce the respective stampings such that the finished parts will nest together very closely. But in addition to this requirement the welding dies must gage the parts, before welding actually takes place, simply and precisely in the proper location. In the preliminary engineering sketches mutually exchanged between the McIntosh Stamping Corp. and the Swift Electric Welder Co., a novel and simple solution to this problem was evolved. By coining the two projections on the lower end of the $^1/_4$-in. rear stamping and then setting it up in the projection welding die at an angle of 45° and dropping the $^3/_{16}$-in. front stamping down over the former and supporting the overhanging, protruding arms of this stamping for balance only it was visualized that uniform and accurate assemblies would be produced over a long period of production. The

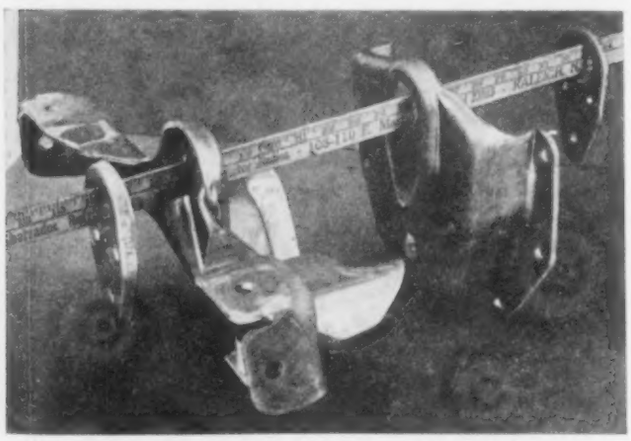


Fig. 3—Exploded View of the Resistance Welded Assembly in Fig. 1

striking principle here being that one surface having four projections is welded simultaneously and in conjunction with another surface of the same stamping which is at a right angle to the first and contains two projections. It should also be realized that this solution eliminates two of the six separate spot welds.

The inherent nesting qualities of the design of the $^1/_2$-in. reinforcements and the two large stampings, which were mentioned previously in conjunction with the coining of the projections in the $^1/_2$-in. steel plate, were incorporated for gaging purposes irrespective of the method of assembly.

Figure 3 shows an exploded view of the four stampings of the final design in their respective positions before assembly (reinforcements are actually reversed). The natural nesting qualities of these four stampings should be here noted as well as the fact that one stamping is entirely free from projections or locating lugs of any nature.

Figure 4 (*a*) shows a dimensional design of projections used on the $^1/_2$-in. steel reinforcing plates. There can be noted a circular depression or portion of a torus, surrounding the projection itself and coined into the surface of the stamping. Such a depression was recommended by the Swift Electric Welder Co. to consume part of the

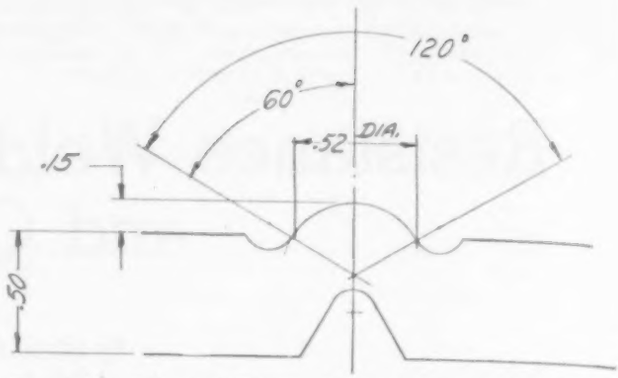


Fig. 4 (*a*)—Spherical Radius of Projection = 2.72 Radius of Depression with 120 Degrees Constant and Independent of Project on Diameter and Height

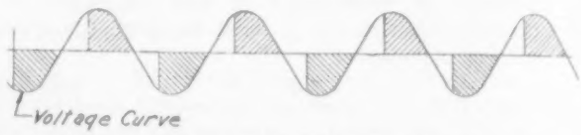


Fig. 4 (*b*)—Shaded Area Under Curve Indicates the Portion of Each of 90 Cycles During Which Welding Current Flows for 3 of the Above Projections

volume of the projection thus allowing the two mating stampings to come tightly together without flash between them and also to reduce the cross-sectional area of the projection at its circumference to give a more uniform heating over the entire projection during welding. The design of this projection was made such that the volume of the part of a torus below equals approximately 70% of spherical portion above the surface of the stamping.

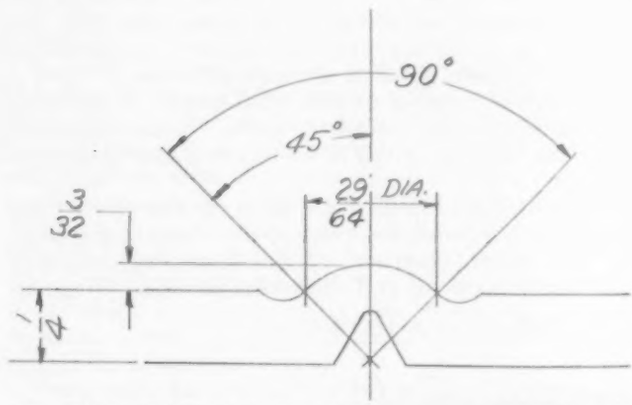


Fig. 5 (*a*)—Spherical Radius of Projection = 3.16 Radius of Depression with 90 Degrees Constant and Independent of Projection Diameter and Height

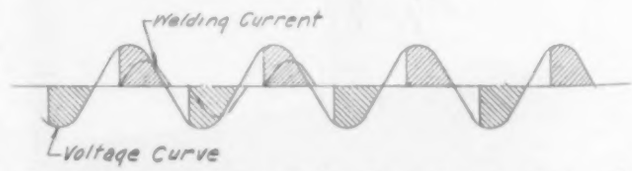


Fig. 5 (*b*)—Shaded Area Under Curve Indicates Portion of Each of 90 Cycles During Which Welding Current, Broken Curve, Flows for 6 of the Above Projections

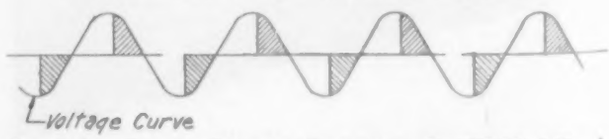
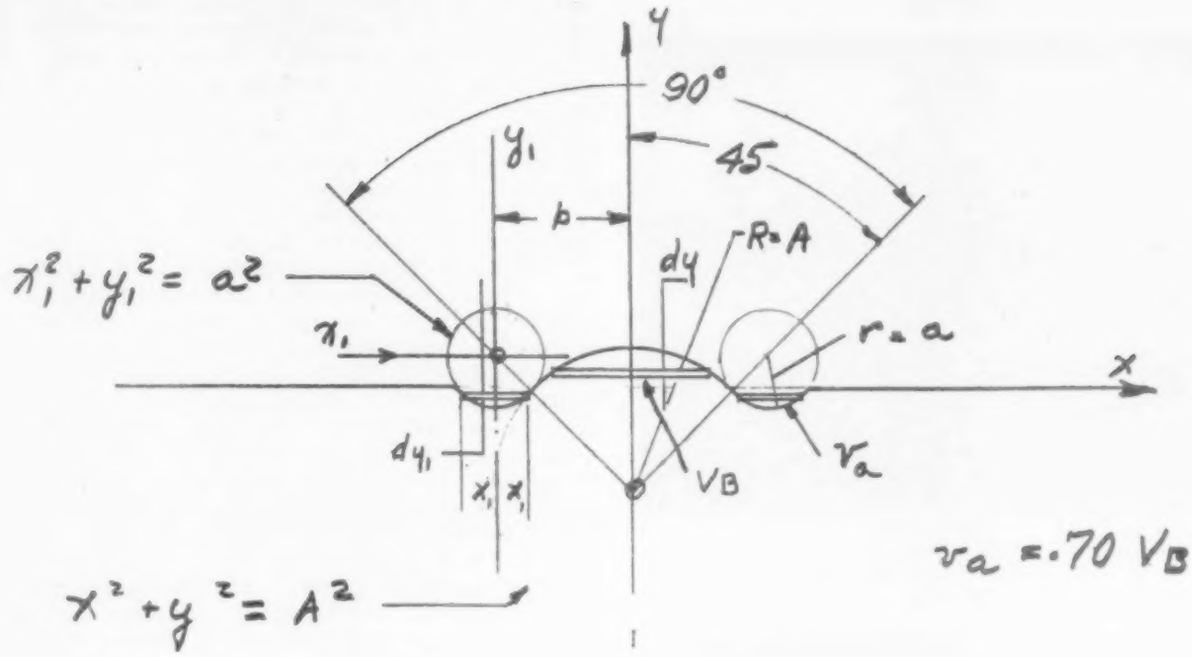


Fig. 5 (*c*)—Two $^7/_8$ Diameter Projections Are Welded Simultaneously in $^3/_{16}$ and $^1/_4$ Inch Steel by Welding Current During Each of 90 Such Cycles Drawing 1000 Amps. @ 480 Volts



For a spherical projection, as in Fig. 4 (*a*), having normals at the surface of the stamping forming an included angle of 120° the following formula gives the radius A of the sphere in terms of the radius a of the torus:

$$A = 2.72a \qquad (1)$$

For a spherical projection requiring a lesser height in proportion to its diameter such as the projection shown in Fig. 5 (*a*) and its normals forming an included angle of 90°, the formula 1 becomes:

$$A = 3.16a \qquad (2)$$

Proof for formula 2 follows.

Solution

Let volume of spherical portion of projection = V which is made up of circular disks of radius X and thickness dy then:

$$\text{vol. of each disk} = \pi x^2\,dy$$

and ∴

(1) $V = \pi \int_{A/\sqrt{2}}^{A} x^2\,dy; \qquad x^2 = A^2 - y^2$

(2) $V = \pi \int_{A/\sqrt{2}}^{A} (A^2 - y^2)\,dy$

(3) $V = \pi\left[A^2 y - \frac{y^3}{3}\right]_{A/\sqrt{2}}^{A}$

(4) $V = \pi\left[\frac{2}{3}A^3 - \frac{5}{6}\frac{A^3}{\sqrt{2}}\right]_{A/\sqrt{2}}^{A}$

(5) $V = \pi A^3\left(\frac{5.66 - 5}{8.48}\right)$

(6) $V = 0.0773\pi A^3$

Using new coordinate axes x_1, y_1.

Let volume of torus portion = v which is made up of circular rings of outside radius $(b + X)$, and inside radius $(b - X)$ and thickness dy then:

$$\text{vol. of each ring} = \pi[(b + x_1)^2 - (b - x_1)^2]\,dy$$

and ∴

(7) $V = \pi \int_{-a/\sqrt{2}}^{-a} [(b + x_1)^2 - (b - x_1)^2]\,dy$

(8) $V = \pi \int_{+a/\sqrt{2}}^{+a} (4bx_1)\,dy; \qquad x_1 = \sqrt{a^2 - y^2}$

(9) $V = 4\pi b \int_{a/\sqrt{2}}^{a} \sqrt{a^2 - y^2}\,dy$

(10) $V = 4\pi b\left[\frac{1}{2}y\sqrt{a^2 - y^2} + \frac{1}{2}a^2 \arcsin\frac{y}{a} + c\right]_{a/\sqrt{2}}^{a}$

(11) $V = 4\pi b\left[\frac{a^2\pi}{4} - \left(\frac{a}{2\sqrt{2}}\sqrt{a^2 - \frac{a^2}{2}} + \frac{1}{2}a^2\frac{\pi}{4}\right)\right.$

(12) $V = 0.57a^2b\pi$

Volume of portion of torus = 0.7 volume of portion of sphere

∴ (13) $0.57a^2b\pi = 0.7 \times 0.077\pi A^3; \qquad b = \frac{a + A}{\sqrt{2}}$

(14) $a^3 + a^2A - 0.132A^3 = 0$ by plotting $\frac{A}{a}$

as abscissa against the remainder as ordinate it is found that $A = 3.16a$ when the remainder is zero, which by substitution checks to nearly $^1/_{10}$%.

Care must also be used in designing the stampings themselves such that the surfaces which are to be projection welded or spot welded are of a smooth and regular contour. This enables dimensioning the forming dies for the stampings and the welding electrodes with the same specific dimensions, thus a good contact over a large area can easily be maintained. Where there is necessarily an abrupt change in contour in the neighborhood of a projection, the welding electrode should follow this contour far enough to supply heat during welding uniformly across the projection. This latter condition is illustrated in Fig. 6.

For all of the four welding operations performed to complete the assembly of the tractor "front axle and radiator support" one 1000 Kva. welder was recommended and used. By the use of two sets of gages the reinforcements are first welded in place in the large

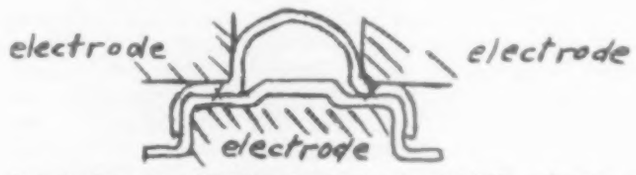
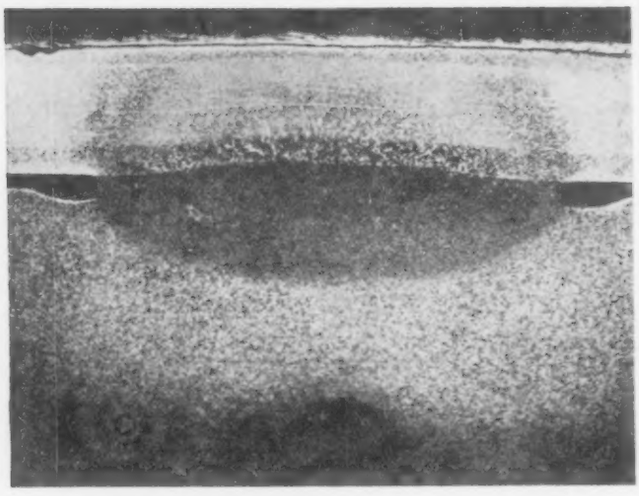


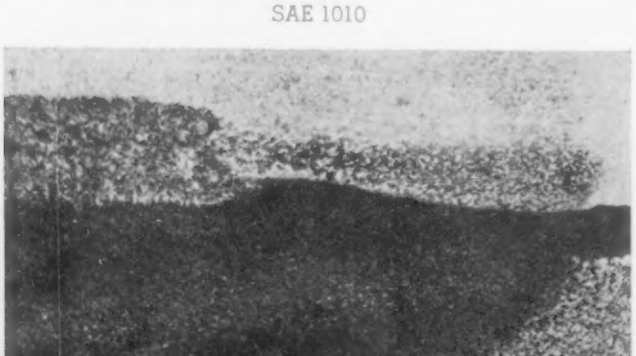
Fig. 6—Projection Welding Electrodes Should Follow Contour of Stampings for a Distance Equalling About Five Diameters of Projection

SAE 1010



SAE 1035
Nital. Shows Entire Weld. × 4

SAE 1010



SAE 1035
Opposite Side. Nital. Shows 1/2 Weld. × 8

Fig. 7 (*a*)—Above, 1/4 Inch Steel Projection Welded to 1/2 Inch Steel and Below a Second Weld in the Same Parts

stampings thus requiring one set of welding electrodes and one set up in the machine for both parts. Figure 4 (*b*) shows the percentage of each cycle that welding current flows. Thirty such cycles followed by five "off" cycles repeated twice making a total of three pulsations of thirty cycles each completes the weld of three projections, similar to Fig. 4 (*a*), joining half-inch and quarter-inch steel stampings. In Fig. 7 (*a* and *b*), although parts are open 0.010–0.015 note absence of flash. Inasmuch as only one machine is used for the complete assembly these subassemblies are neatly stacked by the operator's helper in such a manner that they are easily handled back to the welding machine by the use of a roll conveyor and gravity for the succeeding operation.

The third operation of welding the large stampings using six projections as previously outlined is next effected by removing the welding ties used for the subassemblies and inserting the electrodes required for this operation. These two sets of dies being located on the same side of the machine and a pair of permanently located equalizing spot-welding electrodes on the back or opposite side of the welder controlled by separate initiating switches and a relay having one normally open contact and one normally closed contact which is energized by one of the two pairs of initiative switches allows the third and fourth operations to be run alternately without any further change in machine setup or controls. After the third operation the assembly is placed upon a semicircular conveyor to conduct the assembly around the end of the welder where a second operator performs the fourth operation, namely, four spots—two hits.

Figure 5 (*b*) shows the percentage of each cycle that welding current flows for the third operation and Fig. 5 (*c*) similarly indicates current flow for the fourth operation. Both operations being accomplished in three pulsations of 30 cycles on and 5 cycles off. Each complete operation is controlled by a MEMA Type 4A electronic sequence timer as follows: 30 cycles squeeze; 30 cycles heat; 5 cycles cool; 30 cycles heat; 5 cycles cool; 30 cycles heat; 60 cycles hold time. During the third pulsation a solenoid valve for high pressure is energized by an electronic time delay relay set for 100 cycles starting at the beginning of the squeeze time and an additional forging pressure is thus delivered at the weld.

During each cycle of "heat time" metered out by the sequence timer, a "peaker" transformer controlled by the resistance of a variable potentiometer and the lag due to inductance of the primary of another transformer allows the grids of the thyratron tubes in the phase shift heat control which fire the large *D* size ignitron tubes to become positive, thus determining the exact point in each cycle where welding current starts to flow. The relay energized by one pair of initiating switches at the welder opens the circuit to one potentiometer and closes that to another thus allowing welding current to flow for a different percentage of each half cycle required for welding at the back of the welder than at the front and hence different amounts of heat.

Upon completion of the four spot welds, which is the final assembly operation, one out of every ten assemblies is inspected visually for welds and is then placed in a checking fixture which checks all bolt holes and mounting surfaces of the 3/16-in. front stamping relative to the 1/4-in. rear stamping.

The industrial electronic equipment used in connection with this project was required in order to reduce skilled supervision and maintenance costs to a minimum. However, electronic controls alone are not sufficient to insure uniformity. A constant source of electric power with a

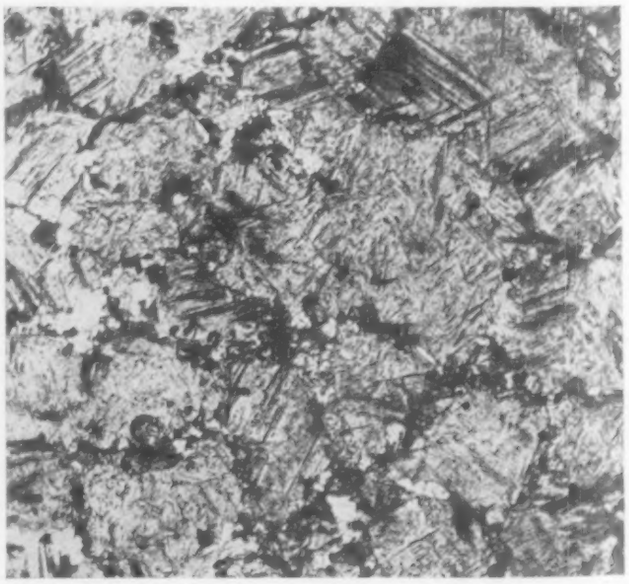


Fig. 7 (*b*)—At Center of a Projection Weld in 1/4 and 1/2 Inch Steel × 150

voltage fluctuation of less than 10% is recommended for satisfactory results. By erecting a cage, within 3 ft. of an end of the welder, to house this electronic equipment, all controls are thus located as close to the machine as possible. Approximately 60 ft. of "Bull Dog LoX" (low reactance) bus conveys the power from the air-circuit breaker which is mounted in a small switch house outside the manufacturing building proper. Adjacent to the circuit breaker is the Detroit Edison meter which is in turn less than 15 ft. from a 1000-kva. transformer substation. The power arrives here by way of an underground cable at 24,000 v. potential and is stepped down to 480 v., see Fig. 8.

The following copy of results of a welder test, very graciously performed by the Detroit Edison Co., shows the approximate current and voltage drop for the third and fourth welding operations pertaining to the "front axle and radiator support":

Date of Test: March 8, 1945
Welder Tested: 1000-Kva. Projection Welder, Manufactured by the Swift Electric Co. Serial No. 982, Type 77, 440 V., 60 Cycles

The welder has two 500-kva. transformers, one on each end of the machine. Two transformers operate in parallel. There are six taps on the transformers as follows:

Tap No.	Voltage Ratio	Full Wave Primary Current (Manufacturer's Estimate)
1	440/8.47	2260 amp.
2	440/9.36	.....
3	440/10.47	.....
4	440/11.28	.....
5	440/12.22	.....
6	440/13.33	3575 amp.

All stock welded was SAE 1010 steel. This was a double machine, arranged with dual controls in such a way that one operation could be performed on one side of the machine and another operation at the other. These operations had to be performed one at a time and could not be simultaneous.

The heaviest weld made was a projection weld on one $^3/_{16}$-in. thick and one $^1/_4$-in. thick stock with 6 projections. The projections were spaced 2 to 3 in. apart, were about $^1/_8$ in. in diameter, and projected about $^1/_{16}$ in. above the surface of the stock. There was a current of about 1600 amp. pulling the voltage down at the service from a "no-load" reading of 488 v. to 472 v. during the weld. The welder was connected to Tap 1 and the phase shift adjusted for 65% heat.

The weld performed on the other side of the machine was a double-spot weld with two $^7/_8$-in. electrodes spaced on about $2^1/_2$-in. centers, spot welding the same $^3/_{16}$- and $^1/_4$-in. stock together. The welder was connected on the same tap as before but the phase shift was adjusted for 45% heat. The primary current was about 1000 amp., pulling the voltage down from 490 v. to about 480 v. during the weld. Both of these welds were pulsations welds with about 27 cycles "on," 4 cycles "off," 27 "on," 4 "off" and 27 "on," for a total weld time of about 81 cycles.

The voltage drop through about 60 ft. of 1600-amp. Bull Dog "low-X" bus was about 2 to $2^1/_4$ v. (480-v. base) per thousand amperes.

Test was made with "stop" ammeter, "stop" voltmeter, and cycle counter by Harold Lueck of General Test Division.

Fig. 8—A 1000 Kva. Transformer Substation with Manually Operated Pole Top Switch, 24,000 to 480 Volts

During the production of the first 15,000 resistance welded assemblies recently completed, not one assembly was scrapped by the manufacturer nor was one rejected by the customer due to poor welds, however, before the resistance welding tools were completed and ready for production, there were 5000 assemblies made by hand arc welding the parts while they were clamped in assembly fixtures. This method of assembly resulted in a scrap loss of about 4% due to welds missing and warpage after removal from fixtures.

In conclusion, the following breakdown shows the relative economy of three different methods of assembly:

Arc welding requires.....	34 man-hours per C
Riveting requires.....	5 man-hours per C (estimated)
Resistance welding requires	2 man-hours per C

Physical Properties of Sprayed Metals*

By A. P. Shepard†

Specific Gravity

ONE of the most important properties of sprayed metal is its porosity, which permits the retention of oil to a considerable extent. Sprayed metal bearing surfaces are consequently self lubricating to a large degree. Retention of oil at the pressure point of bearings, even when the surface is flushed with oil, materially reduces friction and wear. In addition to its function in aiding lubrication and reducing friction, the porosity provides disposal points for small abrasive particles resulting from initial wear.

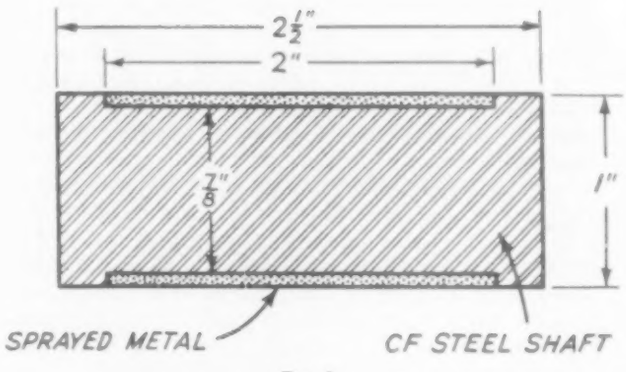


Fig. 1

* Ed. Note: "This report on the specific gravity of sprayed metal is the first of a series. Other reports on physical properties will be published as they become available." Reprinted from Metco News.

† Manager, Metallizing Engineering Co., Inc., Long Island City 1, N. Y.

Fig 2

It will be seen, therefore, that the advantages of porous structure are considerable whenever bearing surfaces, reciprocating or rotating, are involved.

It was determined that the specific gravity of sprayed metal, as compared with the original wire, would be a reasonably accurate measure of porosity. This assumption ignores differences in weight between the metal and the oxides which are present in sprayed metal. However, the difference in weight is slight, and the per cent of oxide is so low that the assumption is considered valid for purposes of determining porosity in bearing applications.

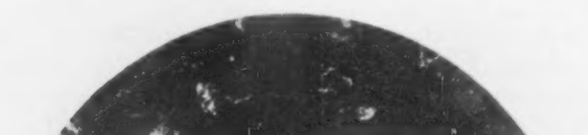


Fig. 3

Microscopic examinations of specific samples sprayed under controlled conditions clearly show the porous structure. Shown in Fig. 2 are two photomicrographs of Sprairon A at 60 ×. This metal was sprayed on a cylindrical surface. The picture on the left illustrates a section perpendicular to the axis, and the picture on the right a section parallel to the axis. Figure 3 shows a cross section of a sprayed coating of Sprabronze C at a magnification of 300 ×.

A standard procedure was set up for determining the specific gravity of sprayed metal coatings as follows:

Cylindrical specimens were made from cold-finished carbon steel in accordance with Fig. 1. No attempt was made to machine these accurately, since it was considered that the maximum reasonable accuracy would be insufficient for the final determination.

Machined approximately, each individual specimen was measured very accurately, numbered and its measurements recorded on a chart. After spraying, each specimen was ground to diameter D, and the accurate measurement recorded. Volume of the base metal and volume of the sprayed metal were then accurately calculated for each specimen, after which each specimen was accurately weighed, and the specific gravity calculated.

The results, tabulated in Table 1, give the specific gravity of the sprayed metal, and also the per cent of specific gravity to the original wire used for spraying each specimen.

Table 1—Specific Gravity of Sprayed Metal

Sprayed Metal	Specific Gravity	% of Original Wire
Metco Aluminum	2.408	94.1
Sprababbitt A	6.671	86.6
Sprababbitt B	6.653	86.4
Sprabrass Y	7.442	88.3
Sprabronze A	6.927	88.8
Sprabronze C	7.574	86.6
Sprabronze M	7.263	86.9
Sprabronze P	7.676	86.4
Sprabronze T	7.461	89.2
Metco Copper	7.535	84.4
Sprairon A	6.719	88.4
Metco Monel	7.671	86.5
Metco Nickel	7.551	85.8
Metcoloy #1	6.934	88.9
Metcoloy #2	6.742	88.7
Sprasteel 10	6.673	86.7
Sprasteel 25	6.782	88.1
Sprasteel 40	6.943	90.2
Sprasteel 80	6.356	82.5
Sprasteel 120	6.745	87.6
Metco Tin	6.426	88.1
Metco Zinc	6.363	89.0

Welding on the Farm*

By A. H. Hollenberg†

THE increased use of farm machinery on the farms of the country has called for a complementary development of welding facilities and skills. Even on the first pieces of farm equipment, which were made largely of wood, some metal was used. On any farm machinery which has metal as part of its makeup there will be certain wear or breakage. These conditions must be remedied either by replacement of the part or by welding the broken pieces.

There are at least two types of welding appropriate for farm use—oxyacetylene welding and arc welding. In the early days of farm machinery most of the welding of parts was done in a forge, which may be classed as a part of blacksmithing. Although many farms had forges in their repair shops most of the welding that the farmer had done was performed by the blacksmith. This was the case because the farmer did not possess the skill necessary to do an efficient job of forge welding. One of the most common welding jobs accomplished on farm machinery in those days was that of welding a new point on a plowshare.

The oxyacetylene torch followed the forge type of welding on the farm but did not entirely replace it. Oxyacetylene welding was more satisfactory because of the ease of doing the job. The process, however, presented about as many difficulties to the farmer as did forge welding. For this reason the farmer relied on a skilled mechanic to do most of his welding jobs for him. Some oxyacetylene torches have been purchased for use on farms. The oxyacetylene torch has an added advantage in that it can be used to cut both iron and steel. Many farm machinery parts can be heated and straightened, without removing from the machine, by the use of an oxyacetylene torch.

The arc welder has come into the picture in recent years to do its share of welding on the farm. Again, it has not entirely replaced forge or oxyacetylene welding. Many farmers have purchased arc welders and more will probably find a place on farms. The reason for this is the trend toward more mechanism on the farm and also the trend toward larger farm units. Arc welding also requires a rather high degree of skill before an acceptable job of welding on the farm can be assured.

Welding that is done on farm machinery or other equipment on the farm must be just as strong as welding on industrially made equipment. Some have the idea that because it is a piece of farm machinery a poor or mediocre job of welding will serve as well as a good one. It has been noted in the past where an inferior weld has been made on a piece of farm machinery that the weld will not only break but also will cause other costly breakdowns on the machine.

Most of the farm machinery used today is mobile. This equipment will naturally have a tendency to break more often due to the vibration and resulting strain caused by moving it from place to place. This means more welding will need to be done on farm equipment in the future and stronger welds will have to be made.

Welding on the farm may be divided into two phases, that of repairing broken or worn parts of machinery and that of constructing new farm equipment.

The farmer of today is ever confronted with repair work on farm machinery. By and large he is not sufficiently trained to do this job. As a result if he attempts to accomplish this task an inferior job usually results. During the past few years many farmers of the country have had an opportunity to become more or less efficient at welding through adult training courses sponsored by the departments of vocational agriculture in high schools. Since October 1940 approximately 6000 vocational agriculture farm shops have been expanded and further equipped to make more readily available this training service. In this same period approximately 67,548 courses in farm machinery repairing have been made available to farmers. Approximately 1,130,951 farmers have been enrolled in these special courses. Welding has been one of the most important aspects of this special training program. The farmer must rely on a man who is experienced in welding as a part of his trade or the farmer must receive adequate training in welding technique if he is to keep his farm machinery in working condition. It is quite likely that a good share of the farm welding will be done by skilled mechanics because of the fact that the farmer does not have the time to become a skilled mechanic with all the other duties of farming which he must perform. On the other hand, recent experience has shown that many farmers can and do learn many of the skills necessary to do a high-quality welding job.

In the repair of farm machinery an operator is confronted with almost every type of welding. Many parts of this farm equipment are made of cast iron. Welding or brazing is necessary to repair cast-iron parts. Other parts of this farm machinery may be steel of a type which naturally requires a special type of rod and a different treatment while it is being welded.

Most farm machinery is in general made of mild steel. This is the easiest type of metal to weld but it still requires skill in doing the job. Many parts of farm machinery, such as plowshares, shins of mold boards and cultivator points, require hard surfacing which not only requires a different welding technique but is also more difficult.

Some of the most common parts of farm machinery that can be repaired by welding are: broken castings, broken rods, worn cutter bar shoes on a mowing machine cutter bar, knife heads, plowshares, moldboards on plows, broken beams, broken hitches, worn journals, lugs on tractors and broken shafts.

Usually the best means of welding broken parts on farm machinery is to remove the parts to a place where they may be aligned before the weld is made. Then, too, the parts may be properly prepared for welding. In some instances where the removing of many parts or where the task of removing them is a difficult one, the

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weld can be made satisfactorily while the damaged part is on the machine.

Where a lathe is available worn boxings and worn shafts may be built up by welding and then machined to the correct size. During the war emergency many machines have been repaired by using this method.

A farmer almost constantly is confronted with the problem of broken machinery parts. Even though a piece of farm equipment is new there is a possibility of breakage because of an accident or by extra strain placed upon some part of it. Since work on the farm is seasonal, many operations must be performed in a limited time. This means that when a piece of farm machinery breaks the farmer must have it repaired as quickly as possible. Welding is often the most efficient and fastest method of accomplishing this task. Time will also be saved if the farmer has welding apparatus on the farm and if he is skilled in its use.

Some farms are large enough to justify the employment of a skilled mechanic to do this welding on farm equipment. There is also the possibility of small farmers pooling their repair problems and making use of a skilled mechanic for several farms. In both instances a mobile welding shop may be in order. The things needed for successful work in the field are the same as those needed for indoor shops. They are: light, power, tools large enough to do the required job, some shelter and enough heat to permit working in cold weather. A one-ton, two-wheeled trailer will make a practical conveyor for this mobile unit. An adequate arc-welding machine, gasoline motor driven, of 200- or 300-amp. capacity, should be on hand. A trailer equipped with a 300-amp. generator with a.-c. slip rings, giving 3-kw., 110 volts, 60-cycle, single-phase auxiliary power for an electric drill or grinder is good equipment. If oxyacetylene welding equipment is also needed a more elaborate mobile welding shop is necessary. The smallest complete shop should have a built-in forge or oxyacetylene welding equipment, a large anvil stand, a sledge hammer, hand hammers and tongs. Additional pieces of equipment needed are: high-carbon steel work plates, general-purpose supporting jacks, two large vises, a removable two-speed electric drill in a post stand, and an electric tool and work grinder. A 3000-watt, air-cooled gasoline engine driven electric generator is needed for power and lights.[1]

It cannot be stressed too much that a high-quality job of welding be done in repair work on farm machinery and farm implements. One breakdown during a critical harvest season may cause a farmer to lose heavily of his crop. In addition during the break his men are idle and loss of wages occurs. Although welding requires a skilled technique this does not mean that a farmer cannot master it. It does mean, however, the individual who is to do welding on the farm must have sufficient training and practice before he assumes full responsibility for making welds on critical and important parts.

Many farmers are of the opinion that all that is necessary, in order to insure good welding being done on their farms, is to purchase a welding machine. The result, in many cases, is a type of job referred to by some as "gob and dob" welding. This, of course, is a plastered type of job that holds no better than it looks. A weld properly made is equally as strong as the original piece.

Many a new piece of farm machinery must be made over before it fits the particular need of some farm. In this country there are a good many areas where special types of crops are raised which require tools and equipment that are different from those used in other sections. In making such farm machinery over into usable equipment welding is indispensable.

Many farmers today are planning and making many of their farm machines. In this type of work welding equipment of some kind is necessary. Most of the welding done on equipment constructed by the farmer will be on mild steel plate, castings or cast iron. Here again the welding must be of the best. Not only will the farmer need to know how to weld but he must be able to lay out the work and prepare the job for welding, know how large a weld to make and what type and size of rod to use. A farmer may have an idea of how he wants to construct or repair a piece of farm equipment, but if any part is not properly welded he may have trouble with it.

Many labor-saving devices and pieces of farm equipment have been made by farmers in the past few years. This is due partly to the fact that farmers have been receiving more training in welding and partly to the fact that new farm machinery has been hard to secure. Even when new farm machinery becomes available there will be some farm equipment made by farmers, which will entail welding.

Some of the labor-saving equipment that has been made on the farm includes: trailers, buckrakes, manure loaders, sleds, wagons, bean cutters, land floats and the like. None of these can be successfully made without the use of welding equipment.

There are countless odd metal jobs on the farm which require welding; stanchions in the dairy barn, parts on pumps, worn parts on pump jacks, broken hinges and locks and irrigation pipe are some examples.

Before the farmer purchases any type of welding equipment he should ask himself several questions. Will the expenditure of the amount of money necessary to purchase the welding outfit be justifiable? In other words, will it pay interest on the investment which the farmer makes? Am I skilled enough in the use of this device to do an acceptable job of welding or can I become skilled enough in it through training and practice? Have I enough farm machinery on my farm to warrant the purchase of such equipment? Which kind of welding equipment shall I buy if I can justify it? Will a forge be the type of equipment that will accomplish my purpose? Will I have enough shaping and bending of iron, as well as welding, for me to purchase an oxyacetylene torch? Will an arc-welding machine do the job that is necessary or be enough faster to justify its purchase? Can I obtain the type of coal needed for doing a welding job in a forge? Do I have enough welding work to permit me to buy or rent oxygen and acetylene tanks? Do I have the proper type of electricity available on my farm to operate the welding machine I am considering purchasing? If I choose an arc-welding machine will I get an a.-c. or a d.-c. type? These questions and perhaps others must be answered by the farmer before he purchases welding equipment.

In summary, farm welding includes brazing, and welding of cast iron, welding of tool and mild steel and hard surfacing of wearing parts. This job can be accomplished by use of a forge, oxyacetylene torch or arc-welding machine. Welding on the farm is very important to the farmer because it saves him time and assures a good job if done correctly. At present the farmer needs more instruction and practice in welding if an acceptable job is to be accomplished by him. Welding on all farm machinery must be of high grade.

[1] Establishing and operating a Metal Working Shop. U. S. Dept. of Commerce.

Electric Eye Tracing in Machine Cutting*

By Walter Bergerow†

I. Introduction

THE success of the oxyacetylene hand cutting torch, shortly after its commercial introduction at the turn of the century, over mechanical methods of sawing and severing steels, left in its wake a strong demand for a mechanical means to accurately propel the torch over the work piece during the operation. It was evident that greater uniformity of work, higher rates of production and still further reduction in scrap could be realized if a machine designed to control torch movement were to replace the method of guiding the torch manually.

This demand was first expressed in individual plants through makeshift devices adapted to the specific needs of the job at hand. At the outbreak of the first World War, torch guiding machines—relatively crude prototypes of the versatile models available today, though based on the same general principles of operation—began to appear on the market. One of the more popular of these early machines known as the Radiagraph could cut either straight or curved lines. The introduction of this machine marked a great step forward in the oxyacetylene cutting field as the process was no longer limited to severing, or simple straight line cuts. The fact that the Radiagraph was portable served to further increase its popularity as most plants were not adapted to line-production methods and consequently the machine had to be brought to the work. Today we still find the modern, highly adaptable version of the Radiagraph on hand wherever a portable cutting machine is required. As plants became modernized for line production work, stationary machines such as the Oxygraph and Travograph made possible multiple cutting, stack cutting or a combination of both—vastly increasing the productivity of the oxyacetylene cutting process.

It is interesting to note that while the design and development of torch cutting machines and equipment kept pace with industrial demands for improved economy, faster cuts and better quality, the methods of guiding the torch over the work piece remained about the same. The movement of the torch when it is not locked into position for straight line cutting is usually governed by one of three methods—guiding a manual tracing wheel over a drawing, guiding a tracing spindle around a wood template or the use of a magnetic spindle to guide the tracing head against a steel template.

The success of the manually guided tracing wheel is naturally dependent on the ability and skill of the operator and is sometimes responsible for a high percentage of waste due to human error and operator fatigue, when complex cuts are encountered. This method is generally employed when a limited number of cuts are required and template fabrication is not justified. The other two methods depend on hand-made templates constructed with due allowance made for such factors as spindle diameter and kerf width.

As any appreciable variance from the specifications of the desired cut for close tolerance work results in waste, the tailoring operations required for template construction have required skilled labor with manual dexterity equivalent to that of the old fashioned cabinet maker. Furthermore, the most accurate templates are limited to the ability of the tracing device to follow the template contour, making complex shapes cut to exact specifications impossible without elaborate jigs and considerable machining. This disadvantage is particularly evident when inside and outside corners are encountered.

Low cost template preparation cannot be stressed too strongly as one of the most important factors in shape cutting operations. It is generally conceded that until now the most accurate and most automatic form of tracing in machine cutting is accomplished with the magnetic tracing device. To prepare a template for the magnetic tracer a study of the outline of the cut must first be made to determine if the part can be cut in its final desired shape or if certain intricate sections must be obtained by subsequent cutting. The next step is to determine if an inside or outside template is required. Having determined this, the dimensions of the template must be computed making due allowance for roll diameter and kerf width. Provision must also be made for a lead-in slot and finishing finger such as is employed when cutting circles and piercing on the cut line is to be avoided. A drawing incorporating these requirements is then prepared. The resulting outline must then be machined in plate steel to reasonably close tolerances. It is evident that large quantity production is required to offset the cost of such template preparation. A typical example of a magnetic template is shown in Fig. 1.

The problem of proper template storage requires a sufficient allotment of valuable floor space, especially when a variety of shapes are cut. In addition, special storage techniques and frequent inspections are necessary, especially when templates are fabricated from wood, aluminum or other soft materials. Much literature has been written and thought expended in attempts to simplify or standardize template procedure, but this operation remains essentially a special job requiring exacting workmanship each time a new design is required.

There are no limitations to the variety of designs which may be cut with electronically controlled tracing equipment. Electronic equipment traces from outline drawings or silhouettes instead of conventional templates and the electronic tracing head follows the most complex drawings—faithfully reproducing angles and curves with extreme accuracy.

This low cost method of preparing templates on paper opens up an entirely new field in machine cutting as small parts and complex shapes may now be economically

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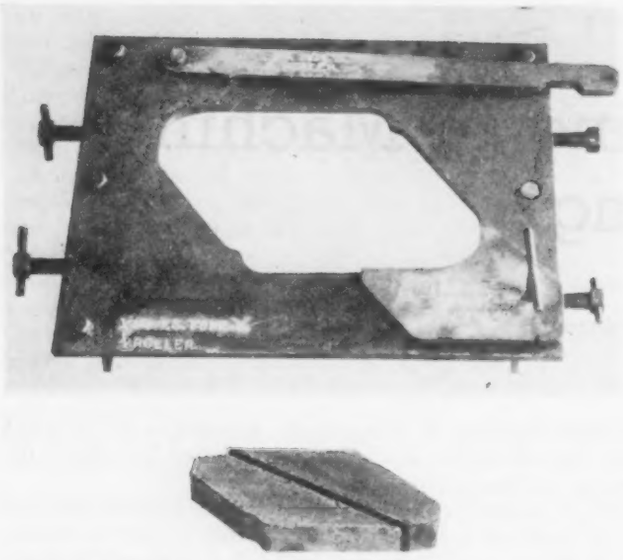

Fig. 1—Example of Steel Template Required for Cutting Machines Equipped with the Magnetic Tracing Spindle. The Electronically Controlled Tracing Device Uses Paper Outline Drawings or Silhouettes in Place of Steel Templates

shape cut for the first time on standard pantagraph machines equipped with electronic tracing equipment. Illustrated in Fig. 2 are two sample cuts—each cut in a single operation from silhouettes. These designs would be impossible to reproduce with any other standard tracing device.

II. Electronic Tracing Device

The photoelectric cell or "electric eye" captured the public imagination in recent years through its marvelous ability to automatically open doors, turn on drinking fountains, etc. Today this control device has been applied to a multitude of industrial problems—wherever fully automatic control of a process can be made more simple than is possible by mechanical control. Therefore, it is not surprising to find electronic control has been applied successfully in the welding field as a means of controlling weld quality in machine welding operations.

Electronic control as applied to oxyacetylene machine cutting is popularly known as the "Electronic Bloodhound" tracing device—the product of extensive research conducted by General Electric and Air Reduction in an effort to adapt all phases of the oxyacetylene steel shape cutting operation to postwar production requirements, while at the same time assuring quality and consistency of cut and materially decreasing the over-all cost per cut. Figure 3 illustrates an oxygraph cutting machine equipped with this electronic tracing device. Where cutting machines are used for plant maintenance work jigs and fixtures may now be economically shape cut when only a few pieces are required and damaged or worn machine parts duplicated with comparatively little effort.

This electronically controlled tracing equipment consists of two units—the tracing head and a control box. The tracing head is a self-contained unit replacing the manual or magnetic device and is attached in the same manner to the bar on standard pantagraph type machines. No modifications or alterations to the machine are necessary. A plan view and elevation view of this arrangement is illustrated in Fig. 4. The control box is attached to the machine base. Electronic equipment makes possible greater cutting accuracy without mechanical aids or human assistance previously required—merely by following the outline of a drawing or silhouette of the desired pattern with extreme accuracy whether the order calls for 1 or 100 cuts.

III. Details of Operation

Nearly everyone acquainted with machine cutting is familiar with the conventional type of manual tracing device illustrated in Fig. 5. This type of tracing device moves the arms of the pantagraph by the tractive force exerted between the driving wheel and the surface of the table with which it makes contact. The driving wheel is rotated by means of shafts and gears motivated by the tracer motor positioned at the top of the unit. The direction of travel is affected by rotation of the driving wheel about a vertical axis. Such a tracing device is guided manually over a drawing or template by the operator. In shape cutting, the operator is called on to steer or rotate the tracer an exact amount at the proper instant.

As our primary interest in electronic control lies in its application to the oxyacetylene cutting process, we will emphasize the method by which the tracing head controls torch movement in this section, rather than explain in detail the electronics involved in the control box operation. The control equipment in the tracing head and control

Fig. 2—Two Sample Cuts, Each Produced in a Single Operation with Electronic Tracing Equipment. Such Designs Would Be Impossible to Reproduce with Conventional Tracing Equipment

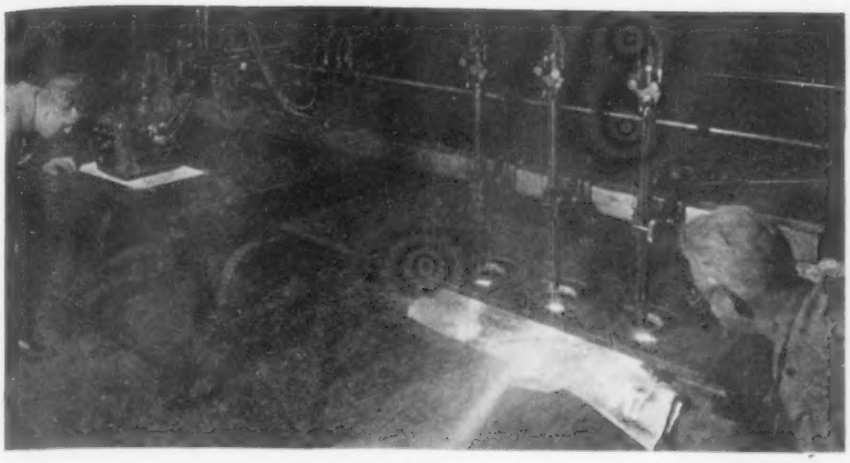

Fig. 3—Electronic Tracing Equipment Installed on an Oxygraph Cutting Machine. This Equipment May Be Installed in Place of Manual or Magnetic Tracing Device on Any Pantagraph Type Machine. No Alterations Are Necessary

box is illustrated in Figs. 6 and 7. Primarily, this method of torch control is fully electric—all parts such as motors, switches, electronic circuit and optical system are completely enclosed as a precaution against oxide, slag, dirt, rough handling and other conditions inherent in steel cutting operations. This protection assures trouble-free operation and the electronic tubes are designed for long life.

The operation of the steering motor is controlled by light emitted from the base of the tracing head which is reflected back from the drawing or silhouette and picked up by phototubes. This light which follows the outline of the drawing or silhouette is projected in the form of a spot from a light bulb through an optical unit containing lenses and a prism. This arrangement is illustrated in Fig. 8. The optical unit is in the form of a tube supported by a vertical bearing and is free to rotate about its vertical axis. The light gathered by the optical system is concentrated so that when focused on the surface of the template a light spot about $^3/_{32}$ of an inch in diameter is formed. This small light spot is deflected by the prism in the optical unit so that the center of the light spot is offset from the center of the optical unit. When the optical unit is rotated about its center the small spot of light rotates on the surface of the template in a path having a $^3/_{32}$ in. radius or $^3/_{16}$-in. pitch circle. It is this freedom of movement which permits the spot of light to continually seek to position itself half on the black line and half on the white line that gives the electronic tracing head its ability to follow any curve or angle. This is shown in Fig. 8. It is the intensity of this reflected light which controls the movement of the steering motor and for this reason the drawing or silhouette used in place of a template must be made in black against a white background or another color combination of sufficient contrast. The reflected light picked up by the phototubes produces an electric signal, the strength of which depends on the intensity of this reflected light; this signal is then amplified to provide the current which flows through the steering motor armature and causes its rotation. Thus, if the light spot is directed entirely on the black area, much of this light is absorbed and a weak signal is produced. Conversely, if the spot is directed on the white background, most of the light will be reflected back to the photo tubes, producing a strong signal.

When the tracing head is following a straight line dur-

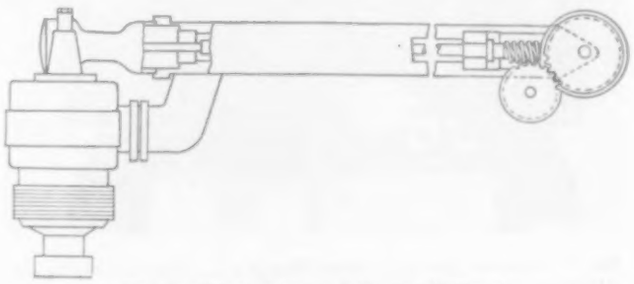

Fig. 5—Typical Manual Tracing Wheel

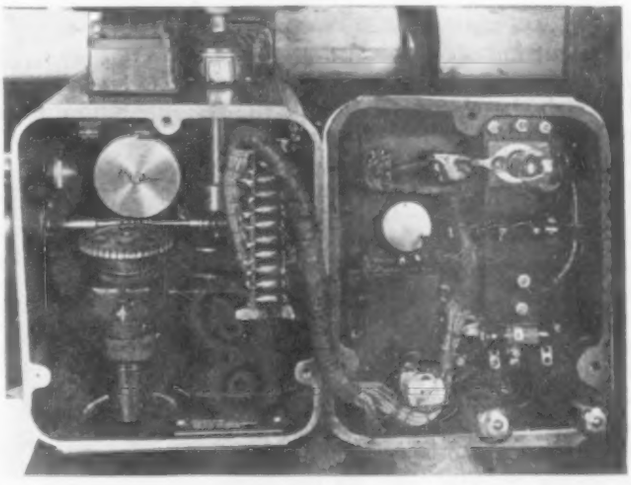

Fig. 6—Internal View of Tracing Head and Cover. The Electronic Tracing Head Is Mounted on the Pantagraph Bar in Place of the Manual or Magnetic Tracing Head. In the Illustration Above, the Phototubes, Amplifier Tube, Light Bulb, Optical Unit and Steering Motor Drive May Be Seen. Also, the Direction Indicator Is Shown at the Top of the Tracing Head

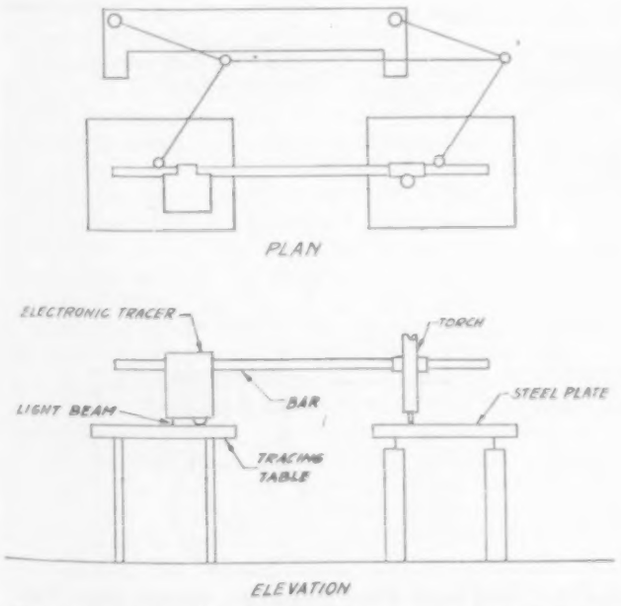

Fig. 4—Plan View and Elevation View Illustrating the Relation of the Electronic Tracing Head to Torch on a Pantagraph Type Machine

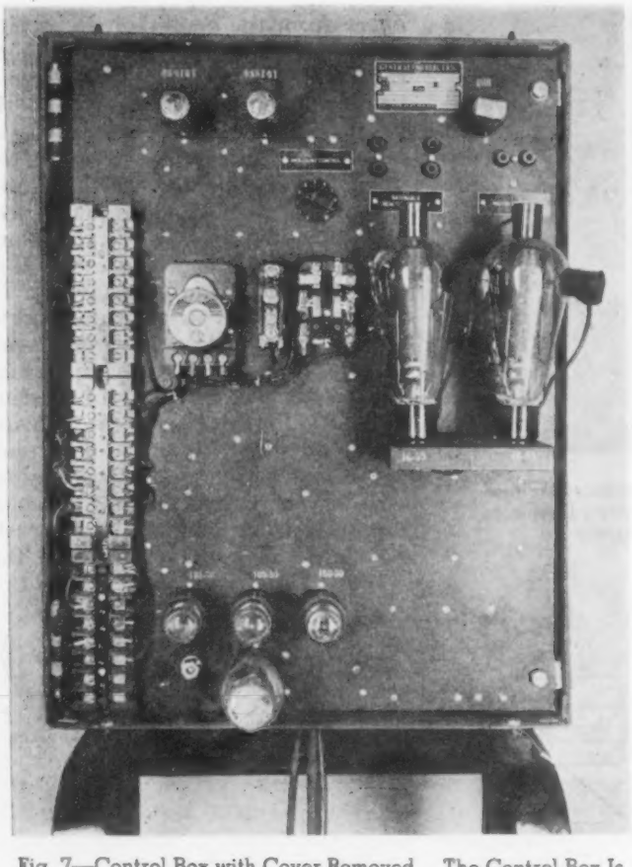

Fig. 7—Control Box with Cover Removed. The Control Box Is Attached to the Machine Base. Illustrated Above Are the Thyratron and Amplifier Tubes and Electronic Circuit Arrangement

ing a cutting operation, the light spot remains centered, half on the black area and half on the white background. Through the electronic circuit, the steering motor is so adjusted that when this condition exists, no rotation of the steering motor armature takes place. This is illustrated in Fig. 9. If more than half the spot of light should cover the black area, a resultant decrease in signal strength causes the steering motor armature to rotate both the optical system and the tracer spindle in a counterclockwise direction until equilibrium has been restored—thus again neutralizing the signal and causing the steering motor to become inoperative as shown in Fig. 10. In the same manner, if the light spot should tend to leave the black outline and more than half the spot became centered on the white background, the strong signal produced by the increased light intensity would cause the steering motor to rotate the optical system and tracer spindle in a clockwise direction until equilibrium has been restored as shown in Fig. 11.

In this operation the optical unit is free to rotate about its center in the same manner in which the tracing device rotates. The optical unit and the tracing device are connected by means of a worm gear drive so that the units rotate simultaneously an equal amount in the same direction when driven by the steering motor.

When a curved line is followed the light spot will transmit a constant slight or strong signal, depending on the

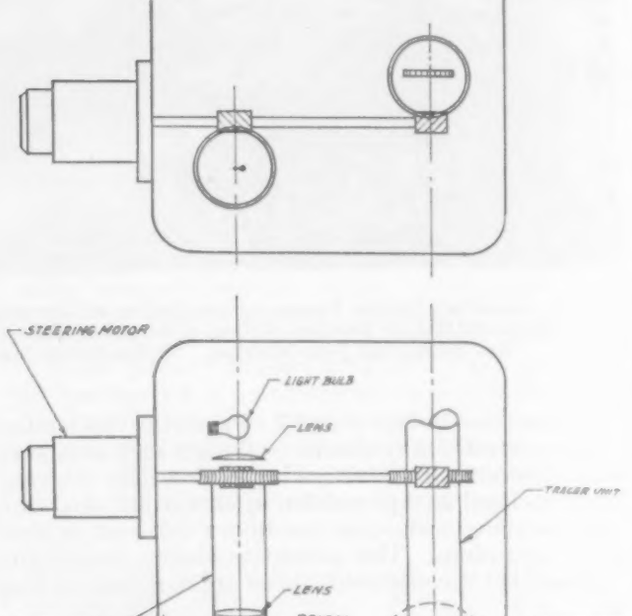

Fig. 8—Arrangement of Optical Unit, Tracer Spindle, Steering Motor and Worm Gear Drive in the Tracing Head. Note That the Light Spot Is Deflected Approx. $^{3}/_{32}$ In. from the True Center of the Optical Unit

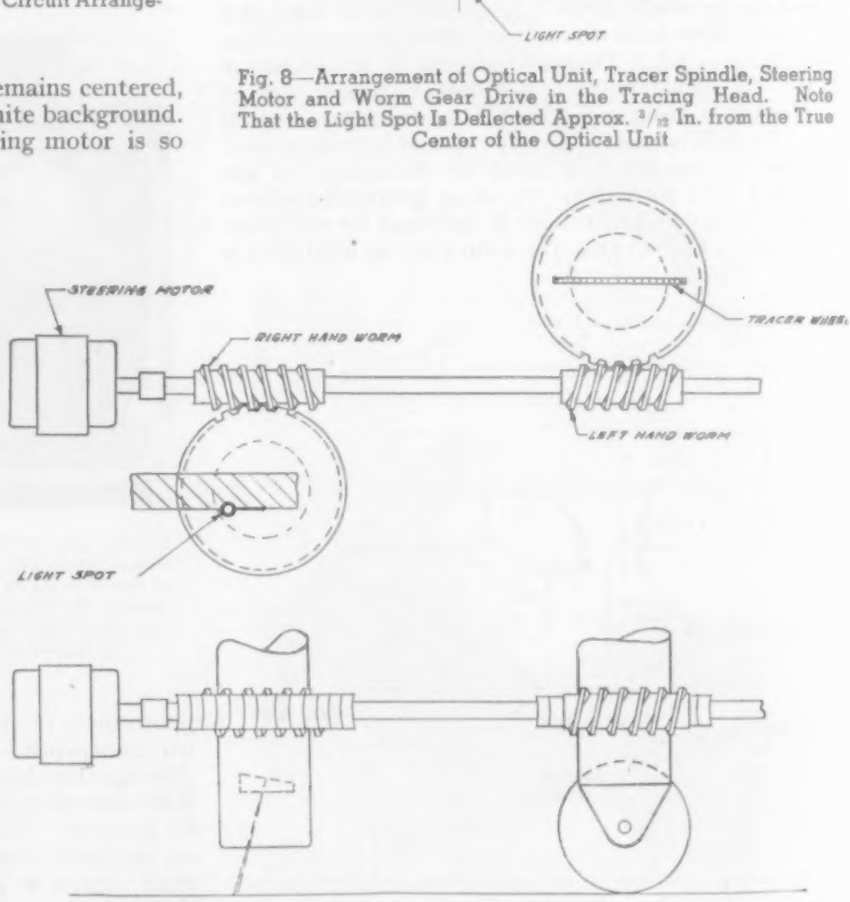

Fig. 9—Operation of Tracing Head When Following a Straight Line. The Light Spot Is Centered, Half on the Black Outline and Half on the White Background. When This Condition Exists, No Rotation of the Steering Motor Armature Takes Place

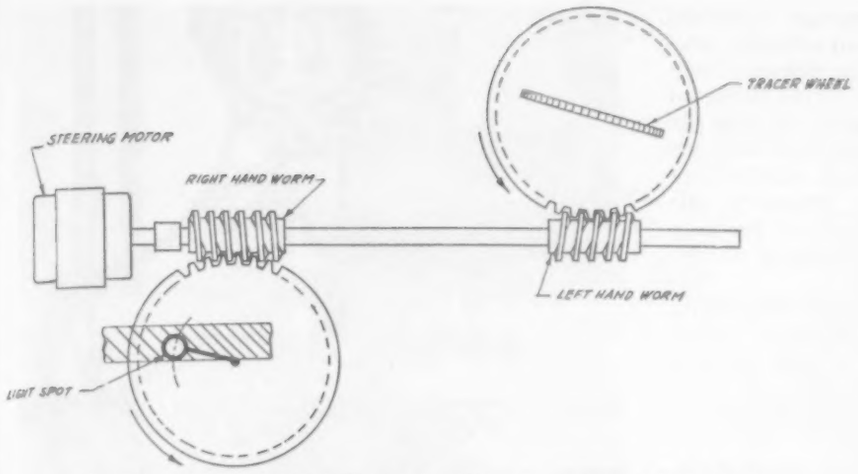

Fig. 10—Operation of Steering Motor When More than Half the Spot of Light Is Directed on the Black Outline. Decreased Signal Strength Causes the Steering Motor Armature to Rotate Both the Optical System and the Tracer Spindle in a Counterclockwise Direction Until Light Equilibrium Has Been Restored

direction of the curve, so that the tracing head follows the curve evenly and, with the aid of an antihunt device, produces a smooth cut. In this manner, the tracing head can continue to follow around a complete circle.

Cumulative errors due to slipping of the driving wheel which are prevalent in other methods of torch control have been eliminated as the electronic tracing head constantly compares torch position directly with the drawing. Also, the fact that this control provides a smooth, even corrective action as the spot varies from its correct position instead of full on or off control, assures correction which is proportional to the amount of error.

When square corners or sharp angles are encountered, two factors will affect the accuracy of the cut to some degree at high or low operating speeds but are insignificant at average cutting speed.

These errors are shown in the illustrations in Fig. 12 which have been considerably exaggerated. Figure 12 (*A*) shows the electronic tracing device approaching a right angle corner at average cutting speed. Note that the center of the optical unit (which would also be the center of the light spot if it were not deflected through a prism) is centered on the edge of the drawing as is the projected light spot. The torch tip at the other end of the pantagraph bar is in the same plane as the center point of the optical unit. In Fig. 12 (*B*) the light spot is about to enter the white field. The projected light spot and the optical unit are still centered on the edge of the drawing. In Fig. 12 (*C*) the light spot is entirely in the white field and rotation of the optical unit and tracer spindle has started. Note the optical unit is still centered on the edge of the drawing. In Fig. 12 (*D*) the light spot is approaching the dark field and the center of the optical unit has now left the edge of the drawing. Figure 12 (*E*) shows the light spot again centered on the edge of the drawing and the center point of the optical unit (which corresponds to the torch position) has rounded off the corner and is again nearly centered on the drawing. In Fig. 12 (*F*) the center of the optical unit has passed beyond the horizontal side of the angle due to the inertia of the machine carriage. The cut produced is indicated in the diagram of Fig. 13 (*C*). Again, it is pointed out that these diagrams have been greatly exaggerated for the purpose of this discussion.

When the operating speed is slow as would be the case in cutting heavy material, the true position of the torch does not correspond to the true position of the light spot, as we have just seen, but there is not enough inertia to cause the driving wheel to skid and consequently a cleanly rounded corner is produced as is illustrated in Fig. 13 (*A*).

The second factor, the high spot following the corner, is evident at operating speeds above average which are encountered when light material is cut. In this case, the increased inertia of the machine carriage causes the driving wheel to skid when the turn is made, producing a high spot, but no rounded corner, as may be seen in Fig. 13 (*B*).

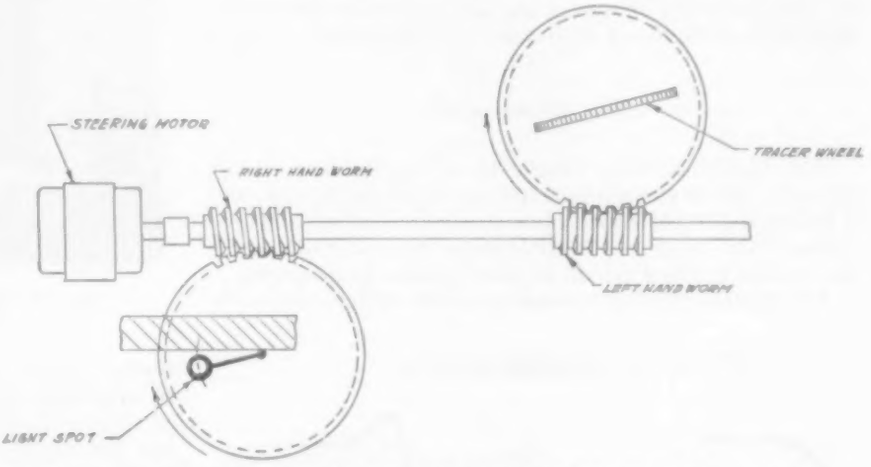

Fig. 11—Operation of Steering Motor When More Than Half the Light Spot Becomes Centered on the White Background. Increased Signal Strength Causes the Steering Motor Armature to Rotate Both the Optical System and Tracer Spindle in a Clockwise Direction Until Equilibrium Has Been Restored

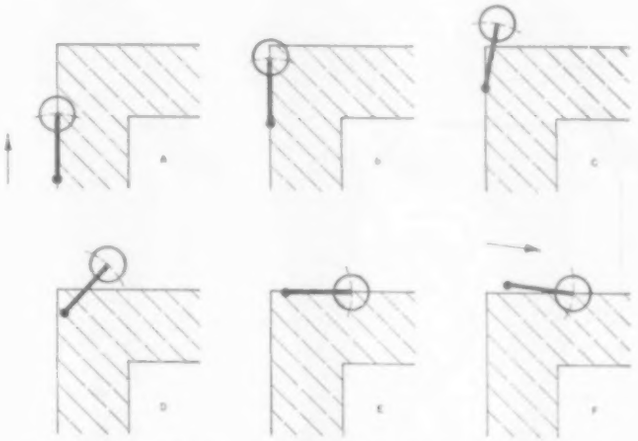

Fig. 12—Error Produced When Sharp Angles or Corners Are Cut at Average Operating Speed. This Diagram Has Been Greatly Exaggerated to Show the Relative Positions of the Light Spot and the Center Point of the Optical Unit When a Corner Is Cut. The Actual Error Produced Is Negligible for Most Requirements

However, we have seen that at average operating speeds the cut will fall between these two extremes producing a corner sufficiently square, as the distance from the center of rotation of the optical unit to the deflected light spot is approximately $^{3}/_{32}$ in.—thus decreasing the margin of error proportionally. If the distance between these two points was even as much as $^{1}/_{8}$ in., the error of the actual cut would be $^{1}/_{32}$ in. or less. Actually, this error is further reduced as the high spot is partially burned off by the increased heat which builds up at corner cuts.

However, a more precise operation may be secured by building up the edge of the drawing as is shown in Fig. 13 (*D*). The extent to which the drawing is built up is, of course, dependent on the operating speed but as previously stated, this minor modification is not necessary for most operations.

It is well to mention at this point that the actual speed of cutting for a given thickness of steel with electronic equipment corresponds to the cutting speed of machines equipped with conventional tracing devices. The speed is preset before the start of the cut and remains constant during the operation—regardless of the contour of the drawing—cutting shapes in a single operation which have been impossible to cut with standard equipment.

IV. Description

The Electronic Eye Tracer Head is attached on the opposite end of the pantagraph bar from the torches and is connected to the control box by flexible rubber-covered cables. The head may be positioned at any desired location on the bar and is held in place by two hand screws.

The tracing head unit consists of the optical unit; the tracing device which includes two photoelectric tubes, an amplifier tube, light bulb and potentiometers; a direction indicator, the switch panel, adjustment controls and the necessary electric connections. To assure perfect electronic control under all operating conditions the electrical units and optical unit are housed in dust-tight chambers. In addition, three motors are provided which control the tracing head movement—the steering motor, the tracer driving motor and a motor which raises or lowers the head.

A vertical track guides the tracing head when the unit is raised or lowered and the head is equipped with sealed ball bearings throughout. Finger tip control assures responsive operation and the unit may be raised above the table to any desired level by merely lifting the handle of a momentary contact switch. The unit may be lowered to rest on the tracing table by means of the same switch as the movement is controlled by a motor-driven sprocket and chain. The unit is supported by the tracing drive wheel when it is resting on the surface of the table and the resultant slack in the chain permits freedom to float in a vertical plane.

A governor-controlled motor which operates the tracing wheel assures a wide range of speeds to include all thicknesses of material from very light plate to very heavy sections. The cutting speed may be preset or changed during the operation, and absolute control is assured through a tachometer which indicates cutting speed. An observation window is provided in the front face of the tracer head to enable the operator to observe the light spot. This facilitates lining up the spot with the drawing and permits the operator to view the light spot and portion of the template being traversed.

The control switches are mounted on the front face of the tracer head as shown in Fig. 14. A single pole switch

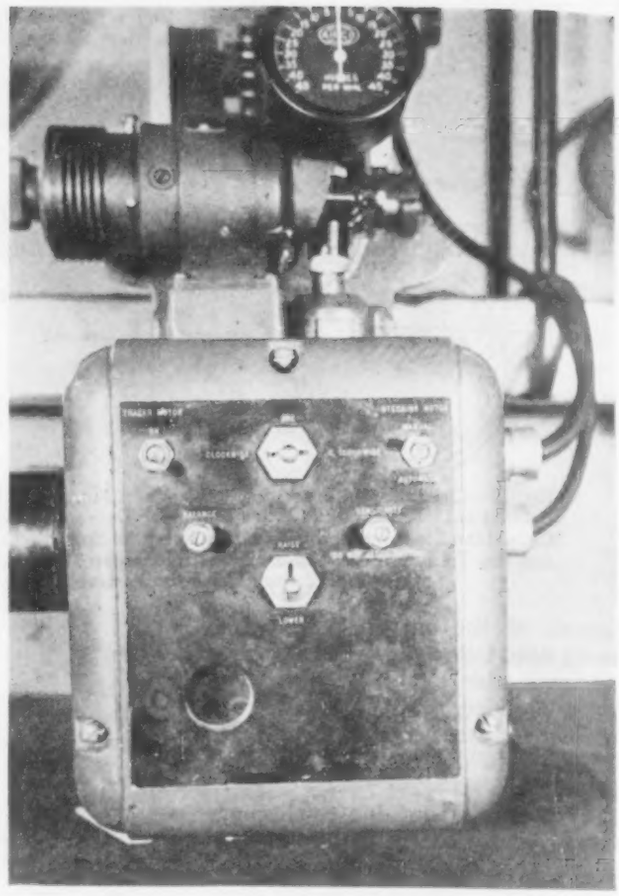

Fig. 14—Switch Panel of Electronic Tracing Head

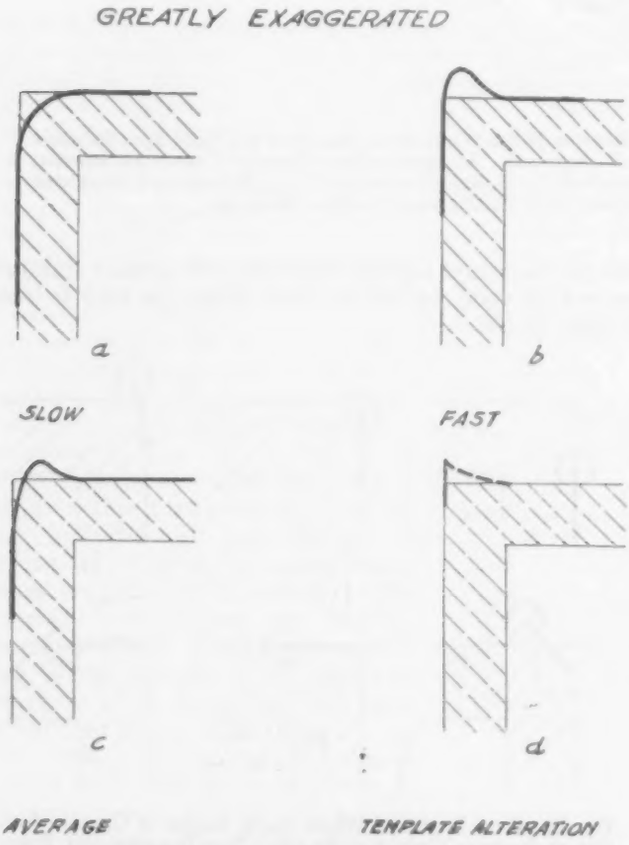

Fig. 13—Types of Errors Produced at Slow, Fast and Average Speeds and Method of Altering the Drawing or Silhouette When Great Accuracy Is Requried. These Errors Have Been Greatly Exaggerated to Show the Variations

controls the tracing device motor. The momentary contact switch raises or lowers the tracer head to permit rapid manual movement of the unit over the tracer table. The scanning head is raised by lifting the switch handle in an upward position and lowered by depressing this handle. Movement of the tracing device wheel may be preset through a momentary contact jog switch. Thus, it is possible by means of this switch to position the tracing device wheel at any desired angle. The manual and automatic switch has been provided for switching off the electronic control during manual operation or for setting the machine on automatic for electronic operation. Two potentiometer knobs adjust the operation of the steering motor.

A unique feature of the Electronic Tracing Device is a direction indicator provided to give visual indication of the angle at which the tracing wheel is set. This may be seen in Fig. 6. As the clearance between the bottom of the tracing device and the tracing table is small to prevent outside light interference, this position would be hard to determine with the naked eye. The dial face of the indicator is calibrated to conform to the numbers on a clock face. If the indicator reads 12 o'clock the tracer head will move directly away from the operator's normal position. Similarly, if the indicator registers 6 o'clock the tracer head moves directly toward the operator—if the dial shows 3 o'clock the tracer head will move directly toward the right, etc.

While discussing directional movement of the tracing wheel, it may be pointed out that it is possible to trace in either direction—clockwise or counterclockwise and the direction desired may be predetermined by positioning the switch provided for this purpose.

V. Drawing and Silhouette Preparation

Drawings or silhouettes for electronic tracing equipment which replace conventional templates are easily prepared by a variety of methods from paper, cardboard or plastic material. Black ink, or heavy pencil lines on white paper, silhouettes inked on a white background or the paper doll method of mounting the design cut from black paper on a white background, are methods which have produced excellent results. Although the black on white combination or vice versa is recommended other color combinations may be used which provide sufficient contrast. Exposed blue printing paper mounted on a white background has been successful. A few examples of these types are shown in Fig. 15. If the inked line for an outline drawing is less than $^1/_8$ in. wide, it should be backed up by a heavy pencil line. It must be kept in mind that the center of the light spot is in line with the center of the cutting tip or cutting oxygen orifice and that allowance for kerf width must be made in establishing the dimensions of the drawing or silhouette.

One of the most interesting features of this reproduction method is the lead-in line, which in the case of these drawings or silhouettes, can be a strip of black paper laid

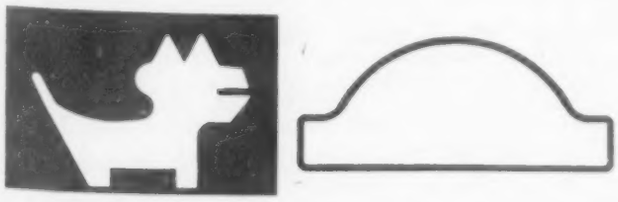

Fig. 15—A Few Examples of Silhouettes and Simple Outline Drawings Which Replace Conventional Templates with Electronic Tracing Equipment. The "Iron Dog" Silhouette Gives a Clear Indication of the Cutting Scope

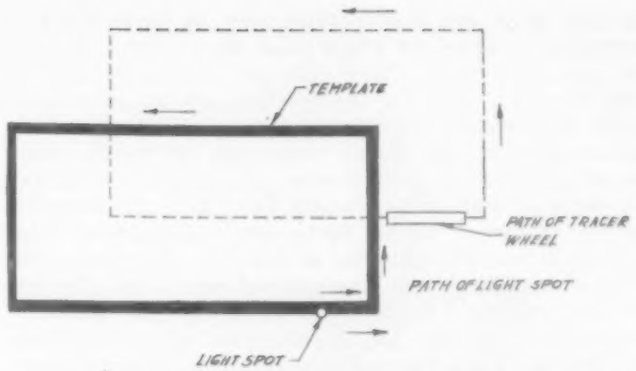

Fig. 16—Path of the Light Spot in Relation to the Tracing Wheel. The Tracing Wheel Does Not Track Over the Outline of the Template Except When It May Intersect the Outline. As the Tracing Wheel Is Smooth, Wear or Damage to the Drawing Is Minimized

on so that the electric eye will follow it in to the outline. The strip may then be removed as the cut progresses.

Dark smudges will, of course, destroy the light contrast upon which the electric eye is dependent to produce true reproductions and, therefore, it is recommended that drawings or silhouettes which are to be used often be protected with a coat of clear lacquer or by cementing a thin sheet of transparent material over the surface. It is well to mention at this point that the tracing wheel does not track over the outline of the template, except where the tracing wheel may intersect the template outline. This is illustrated in Fig. 16. The unit has been designed so that the light spot is offset from the contact point of the tracing wheel. The contact surface of the tracer wheel is smooth and is slightly crowned, thus minimizing wear or damage on the drawing.

The cost of preparing drawings and silhouettes for the electronic tracing device is exceptionally low as compared to templates required by other means of automatic tracing, and still further economy is derived in the simple storage requirements. A boon to every machine cutting department is the speed with which these drawings and silhouettes are prepared. Another advantage is

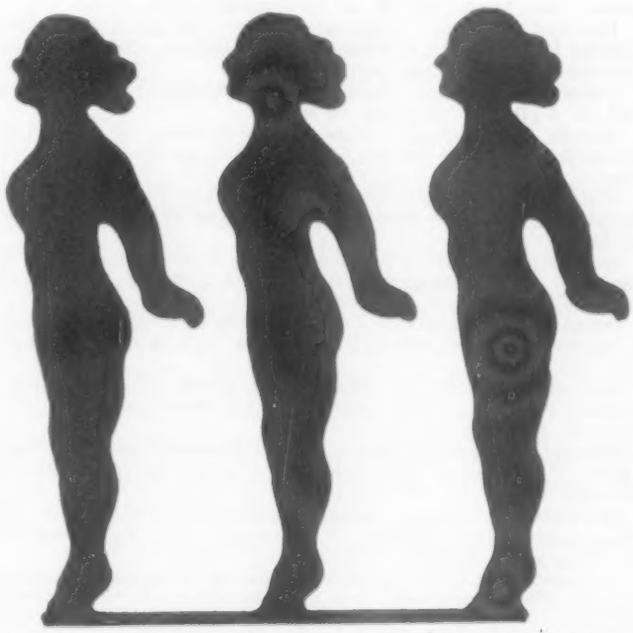

Fig. 17—An Example of the Chain Method of Cutting Is Illustrated in This Silhouette. In This Manner the Cutting Operation Is Continuous When Several Cuts of the Same Pattern Are Made

the ease with which alterations may be made which is particularly important when small dimensional changes are made in a part. These drawings are easily lined up with the work. Another outstanding advantage is found in the chain method of reproduction, particularly in connection with smaller pieces. By chain method is meant reproduction of the outline to be cut in series and joining the outlines with a continuous line, thus enabling the cutting operation to be continuous, eliminating independent starts, as illustrated in Fig. 17. Progressive position of templates may be employed when the same outline is repeated for relatively long lengths when the same design is continuous. This is accomplished by positioning two templates in progression so that one picks up where the other leaves off.

Summary

The accuracy of tracing with electronic tracing equipment is within a very few thousandths of an inch. During a test, the tracer head automatically traced over a drawing of a rectangular design for several continuous hours, using a scribe in place of a torch to scribe a line on a chalked plate, and no appreciable change in the width of the scribed line could be observed. No difference in measurement between the drawing and the scribed line could be detected and extremely difficult and intricate corners presented no tracing problems. During tests conducted with various types of drawings and silhouettes to determine the ability of the Electronic Tracing Head to faithfully reproduce any design, the silhouette of an artistically drawn bathing beauty was tried. The lady in steel possessed all of the charm and appeal of the original.

Thus, we may summarize electronically controlled steel cutting as possessing flexibility, accuracy, economy and quality, far superior to conventional methods of guiding machine torches. Intricate shapes or contours, impossible to cut with other types of tracing devices, may be cut to dimension with this fully automatic equipment. Rapid manual movement from point to point to quickly facilitate lining up the drawing in relation to the material to be cut is assured through control switches. Low cost and ease of drawing or silhouette preparation make possible complex design reproductions while reducing operator fatigue, and the chain cutting technique opens new avenues to increased production.

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(Continued from page 914)

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THE AMERICAN WELDING SOCIETY

ACTIVITIES — RELATED EVENTS

OUR NEW PRESIDENT

W. F. Hess

Dr. W. F. Hess attended Rensselaer Polytechnic Institute at Troy, N. Y., for four years, graduating in 1925 with the degree E.E.; did graduate study at R.P.I. for three years ending 1928 with the degree D.Eng.; was instructor in Electrical Engineering and Physics, R.P.I., 1928 to 1930. In 1929 Dr. Hess began teaching a course in welding to United States Navy Annapolis graduates sent to R.P.I. by the Bureau of Yards and Docks for special training, which has been continued since that date. He was Assistant Professor of Electrical Engineering and Physics, 1930 to 1937; New York State licensed Professional Engineer No. 13,793 since August 13, 1935; Assistant Professor in Metallurgical Engineering, 1937 to 1938; Associate Professor in Metallurgical Engineering and Head of Welding Laboratory, 1938 to 1945.

In 1937, Dr. Hess designed and arranged for the equipment of the present welding laboratory at R.P.I. In 1938 the First Welding Research Committee Fellowship was established for the study of the spot welding of low-carbon and stainless steels. This fellowship was renewed until the present year. In 1945 Dr. Hess was raised to full Professor of Metallurgical Engineering and Head of Welding Laboratory.

W. F. Hess

In 1939 the International Nickel Co. established a Resistance Welding Fellowship, which was continued until the present year.

Establishment of first Aircraft Spot Welding Research Fellowships under the auspices of the National Advisory Committee for Aeronautics, the Army Air Corps and Navy Bureau of Aeronautics was made in 1940 and continued until the present year.

Establishment of first programs of War Research under the War Metallurgy Committee of the National Research Council was made in 1942 and continued until the present.

In 1944 came the establishment of first programs of war research under the Office of Production Research and Development of the War Production Board. Dr. Hess is also consultant on welding problems to the American Bureau of Shipping.

In October 1944 Dr. Hess was awarded the Lincoln Gold Medal by A.W.S. and the University Award of the Resistance Welder Manufacturers Association and in July 1945 was awarded the American Iron and Steel Institute Medal for 1944.

Dr. Hess has held the following offices in the SOCIETY: Chairman, Northern New York Section; District Vice-President, New York and New England District; Chairman, Committee on Awards; Chairman, Educational Committee. He is a member of A.W.S., A.I.E.E., S.P.E.E., A.S.M. and A.S.T.M.

OUR FIRST VICE-PRESIDENT

Harold O. Hill

Harold O. Hill is Assistant Chief Engineer, Fabricated Steel Construction, of the Bethlehem Steel Co., at Bethlehem, Pa. Born in Ontario, Canada, he was educated at the University of Toronto, from which he received the degree of B.A.Sc. in Mechanical Engineering.

He commenced his engineering career with the Riter-Conley Co. of Pittsburgh, Pa. Here he served in many capacities and was Chief Engineer when this company was merged into McClintic-Marshall Co. He became Assistant Chief Engineer of the enlarged company in charge of the engineering on tank and platework.

When McClintic-Marshall Co. was merged with the Bethlehem Steel Co. in 1931 he continued his same duties with the Bethlehem Steel Co.

Harold O. Hill

Mr. Hill was a member of the Board of Directors of the A.W.S. from 1940 to 1943, and has been a member of the A.W.S. Executive Committee for seven yearly terms.

Other engineering activities include the chairmanship of the A.W.S. Technical Activities Committee; chairman of the A.W.S. Committee on the Field of Welding of Storage Tanks; chairman of the A.P.I.-A.W.S. Conference Committee on the Welding of Oil Storage Tanks; member of the A.W.S. Symbols Committee; member of the A.W.S. Committee on Standard Qualification Procedures; member of the A.W.S.-A.W.W.A. Committee which prepared Specifications for the Construction of Elevated Steel Water Tanks, Standpipes and Reservoirs; member of the A.W.S.-A.W.W.A. Committee on the Field Welding of Water Pipe Joints; member of the following Societies, A.P.I., A.S.T.M., A.S.M.E., A.I.E.E., A.S.C.E., Rotary Club, and a registered structural engineer in the State of Pennsylvania.

Mr. Hill has been a member of the AMERICAN WELDING SOCIETY for 14 years.

OUR SECOND VICE-PRESIDENT

George N. Sieger

George N. Sieger, President and General Manager of the S-M-S Corp. of Detroit.

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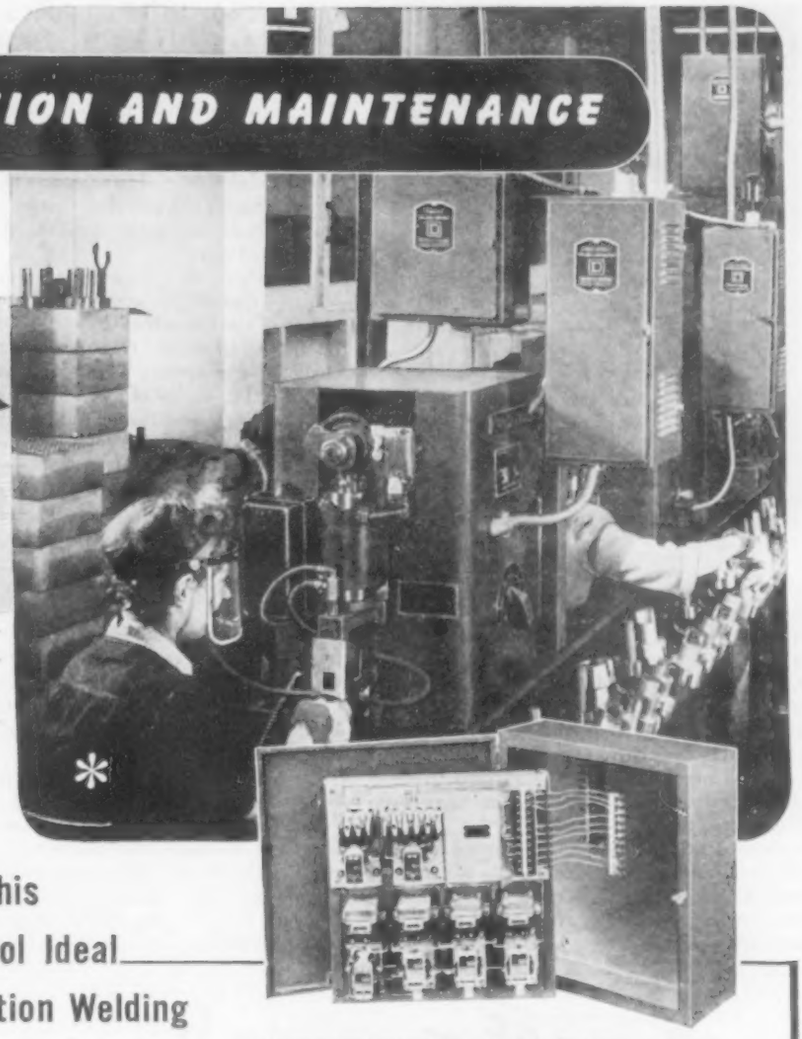

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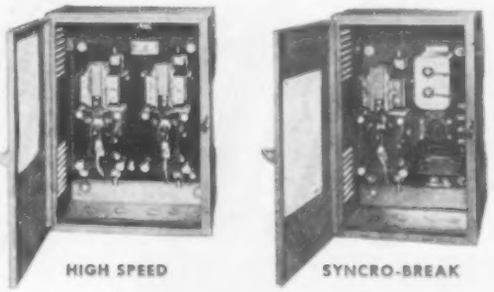

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George N. Sieger

Mich., was born June 19, 1889, in Bethlehem, Pa., the son of Henry N. Sieger who was a manufacturer of snowguards and roofing slate in Slatington, Pa. He attended the public schools of Slatington, and Mercersburg Academy, graduating in 1908. His education was continued at Lehigh University and he graduated from there in 1912 with a degree in Electro-Metallurgical Engineering.

From 1912 to 1914 he was employed by the Continuous Zinc Furnace Co. of Hartford, Conn., as a metallurgist, and when that company was absorbed by the Commercial Research Corp. he remained with the latter organization until 1916 as assistant to the general manager. For the next year he was assistant manager of the Electrolytic Oxy-Hydrogen Division of the Davis Bournonville Co. of Jersey City, N. J., leaving there to go into the service of his country. He was sent overseas where he remained for two years in charge of the production and distribution of non-toxic gas, attaining the rank of captain in the U. S. Army.

Following his release from service he went to Canada to become Managing Director of the Canadian Consolidated Corp. of St. Catharines, Ont., and remained there for five years. The next years were spent in the employ of P. R. Mallory & Co. of New York and Indianapolis, first with the Elkon Works where he became manager of that plant, and later as executive metallurgist, dividing his time between New York and Indianapolis. He served on the board of directors of this company and also found time to help organize the Carboloy Co., serving as technical assistant to the president.

In 1933 he left the Mallory Co. to organize the S-M-S (Specialized Metal Service) Corp., in Detroit, Mich., of which company he was elected President and General Manager and to which he has since devoted his exclusive time and attention.

Several patents in powdered metallurgy are credited to Mr. Sieger.

Mr. Sieger is a member of the AMERICAN WELDING SOCIETY, the Society of Automotive Engineers, American Society for Metals and The Engineering Society of Detroit; is on the Aircraft Welding Standards Committee of A.W.S. and was the first chairman of the Alloy Group of the Resistance Welder Manufacturers' Association. During World War II he served as a member of several Industry Advisory Committees to the Resistance Welding Section of the War Production Board and later on as consultant to the Tools Division of the War Production Board.

Mr. Sieger has been Secretary-Treasurer of the Detroit Section of the AMERICAN WELDING SOCIETY since 1941, is Past-Chairman of the National Membership Committee and Past District Vice-President of the Society.

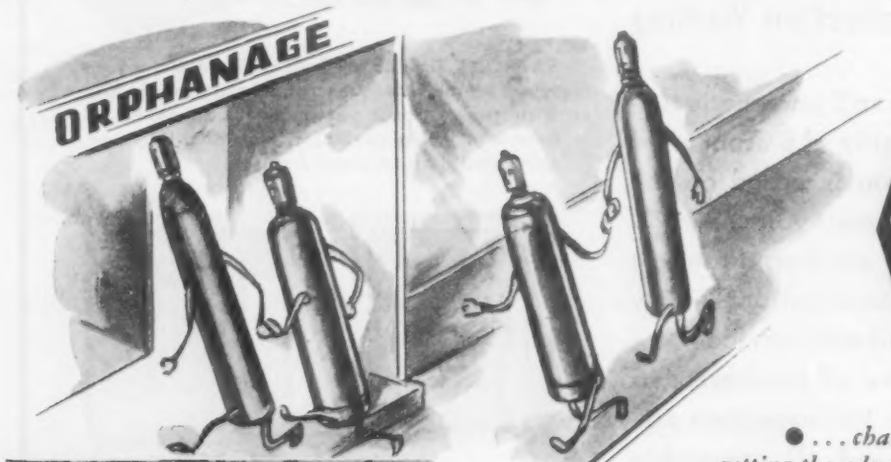
OUR NEW DIRECTORS

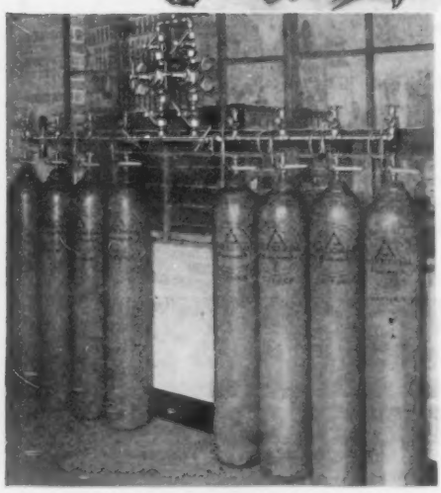
Charles H. Jennings

Charles H. Jennings was born in Des Moines, Iowa, January 23, 1906, and attended Iowa State College at Ames, where he received the degree of Bachelor of Science in Mechanical Engineering in 1928.

Mr. Jennings was employed in the Des Moines Works of the Pittsburgh-Des Moines Steel Co. while still in college, and with this practical experience as a background, was admitted to the Graduate Student Course of the Westinghouse Electric & Manufacturing Co. in 1928, completing the normal year's course in seven months.

In 1929 he became attached to the Mechanics Division of the Westinghouse Research Laboratories in East Pittsburgh, where he instituted advanced studies in the mechanical properties of welds, welding design, welding applications and welding problems.





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F Gas Welders Shield (No. 433), also for arc welders' helpers.

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CESCO safety equipment is designed to provide complete protection and maximum wearing comfort. For example, every device shown on this page incorporates extra features which assure worker safety and help increase production. Besides, CESCO emphasizes top quality in safety equipment—helmets and goggles which stand up under constant use in heavy production. You'll profit by writing for more information *today*.

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CESCO

CESCO FOR SAFETY

Charles H. Jennings

In 1936 he was transferred to the Laboratories' Chemical and Metallurgical Department and put in charge of all the welding research. In 1943 he was made Section Engineer of the Welding Section. Mr. Jennings conducted a course in welding metallurgy at the Carnegie Institute of Technology, prepared a training course for welding operators for the Pittsburgh Board of Education, and is the author of numerous articles on welding and two books—*How to Weld 29 Metals* and *41 Lessons in Arc Welding*.

In 1937 Mr. Jennings was called to England for three months as consultant welding engineer for the English Electric Co.

In 1939 he was awarded the Westinghouse Silver "W" and Order of Merit for distinguished service in welding research and application. He is a past Chairman of the Pittsburgh Section of the AMERICAN WELDING SOCIETY, a past District Vice-President of the SOCIETY and a member of numerous technical committees.

OUR DIRECTORS

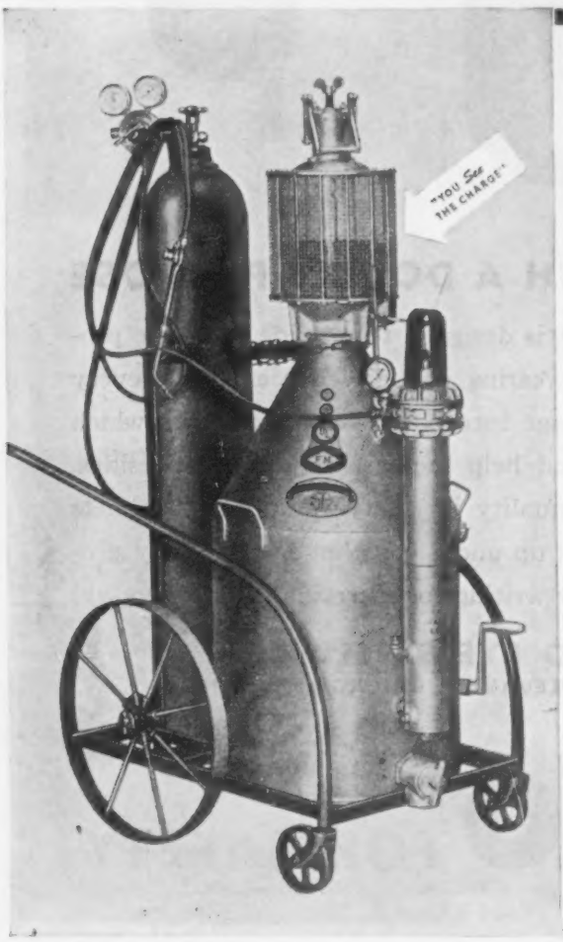
Augustus B. Kinzel

Dr. Kinzel, Vice-President of the Electro Metallurgical Co. and of Union Carbide and Carbon Research Laboratories, Inc., graduated from Columbia University, A.B., in 1919, Massachusetts Institute of Technology in General Engineering, 1921, the University of Nancy, France, D.Met.-Ing., 1922, and he received the degree of Doctor of Science in 1933. Before joining the Union Carbide organization in 1926, he had several years of practical experience as metallurgist with General Electric Co. and Henry Disston & Sons, as lecturer of the advanced courses in metallurgy at Temple University, and as a consultant.

Dr. Kinzel is the author of many papers on the testing and welding of metals, on the metallurgy and physical chemistry of steelmaking, on the composition, physical properties and uses of ferroalloys and alloy steels, and on applied mechanics, and is co-author of the volumes on chromium in the "Alloys of Iron" series of monographs. He holds many patents in these fields. Besides being Past-Chairman of the Iron and

Augustus B. Kinzel

Steel Division and nominee for Director of the American Institute of Mining and Metallurgical Engineers and Past-Chairman of the New York Chapter of the American Society for Metals. Dr. Kinzel was Senior Consultant of the Metals Branch of the War Production Board and is Chief Consultant on Metals to the Enemy Branch of the Foreign Economic Administration. He was also Project Supervisor of the War Metallurgy Committee and is chairman of the U. S. Army Ordnance Advisory Committee of A.I.-



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M.E., Chairman of the Advisory Committee of Dynamic Testing Laboratories, M.I.T., Chairman of the Weldability Committee of the Welding Research Council, member of the International Commission for Acetylene and Welding, and member of the Committee on Metals of the National Academy of Science. Dr. Kinzel was the 1944 Adams Lecturer and is Vice-Chairman and nominee for Chairman of the Engineering Foundation Board and representative to the National Research Council.

R. D. Thomas

Graduated from Cornell University with a degree of Mechanical Engineer (E.E.) in 1906. Early work included operation of an experimental electric furnace; engineering inspector on the new construction of the filtration plant for the city of Pittsburgh. Joined the engineering staff of the Central District and Printing Telegraph Co. (the Bell Telephone System) in Pittsburgh in 1919, and during the following ten years held various engineering positions with operating Bell companies, including transmission engineer for the Pittsburgh district and assistant engineer on special projects in Philadelphia. In 1919, started the firm of R. D. Thomas & Co. as a manufacturer's representative handling equipment to make heat of electricity. Products included electric melting and heat-treating furnaces and electric welding equipment. In 1931, was made Vice-President of Arcos, Inc., and was executive manager of Arcos, Inc., and President of R. D. Thomas & Co. until 1936 at which time the two companies were merged into the Arcos Corp. when he was elected its President, the position he now holds. Arcos Corp. specializes in the manufacture of high-alloy (stainless) and special electrodes.

R. D. Thomas

Hobbies are photography and gardening, the former having been a continuous hobby since 1894.

Member of the Engineers' Club of Philadelphia, and American Society for Metals. Served on the Board of the Engineers' Club for one year 1930–31. Also a member of the Board of the AMERICAN WELDING SOCIETY as representative of the Middle Eastern Division for the years 1937–38. Charter member of the Philadelphia Section of the AMERICAN WELDING SOCIETY which was organized in 1920. Chairman of the Section from April 1927 to April 1929 and thereafter Treasurer of the Section from April 1929 to April 1945.

Carl M. Underwood

Mr. Underwood was born in Denton, Texas in 1902. He received a B.S. degree from Texas A. and M. College in 1925 and a Mechanical Engineering Degree in 1929. He took special courses in Northwestern University and Chicago University.

Mr. Underwood started his career as an engineer in Development Branch, Western Electric Co., working on wire processing, welding plant planning, equipment, welding processes, and development.

In 1933 he became Engineer of Sales, Raytheon Manufacturing Co., Boston, Mass., working on development, design, tests and application of thermionic rectifier type arc welding equipment. In 1934 he became Senior Welding Engineer, U. S. Naval Gun Factory, Washington, D. C., working on application of modern welding to Naval Ordnance equipment including welded design, production methods, radiographic and magnetic inspection, and Navy welding specifications.

After seven years in this position he became manager of Welding Dept., Northern Ordnance Inc., Minneapolis, Minn. His work included building and organizing a

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ECONOMICAL
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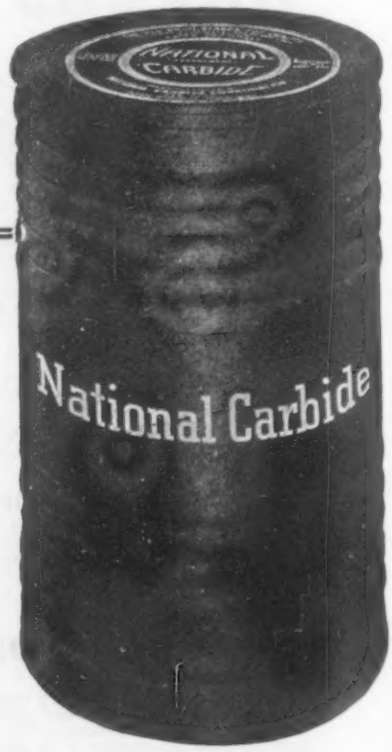

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Carl M. Underwood

complete welding plant for the quantity production of precision type structures used in Naval gun mounts and other Naval Ordnance equipment, welding design, processes, and general management responsibilities.

Mr. Underwood is a member of the AMERICAN WELDING SOCIETY, A.S.T.M., A.S.M. and A.S.M.E. He is a Past-Vice-Chairman, A.W.S., Baltimore Section; Past-Chairman, A.W.S. Washington Section; and Past-Chairman, A.W.S. Minneapolis Section; and a past member of several A.W.S. committees.

DISTRICT VICE-PRESIDENTS

District No. 1—New York and New England

Frank W. Davis

Frank W. Davis, Chief Metallurgist, E. B. Badger & Sons Co., Boston, Mass., was

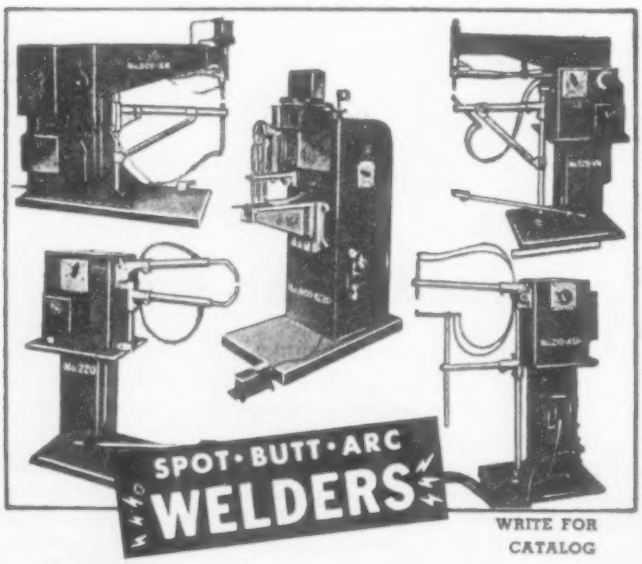
Frank W. Davis

born at Milford, Del., on Sept. 19, 1889. He is a graduate of Lehigh University, 1912, with degree of El.Met., also of University of Nebraska, 1927, with degree of M.S. in M.E.

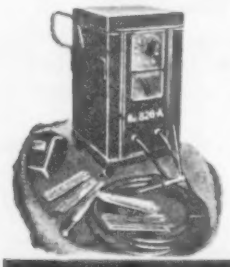
After graduation from Lehigh he was employed by the Electric Storage Battery Co. as foreman in assembly plant. In 1913 he joined the Metallurgical Dept. of the Alan Wood Iron & Steel Co. of Conshohocken, Pa., was placed in charge of this department in 1921. From 1922 to 1927 served as Ferrous Metallurgist for U. S. Bureau of Mines. From 1927 to 1930 was Metallurgical Engineer of International Combustion Engineering Corp. From 1930 to 1933 was President and Chief Engineer of Industrial Gas Engineering Corp. After several years engaged in independent consulting and sales activities he made his present connection.

In addition to the Welding Society he is a member of the A.I.M.E., A.S.M.E., A.S.T.M., A.S.M., and A.P.I. He serves on technical committees of A.S.T.M. and A.S.M.E. For two years he served as chairman of the Boston section of the AMERICAN WELDING SOCIETY. He is a member of the Nebraska Chapter of Sigma Xi. His college fraternity is Phi Sigma Kappa. As for clubs he is a member of the Engineers' Club of Boston and the Henry H. Houston Post of the American Legion of Philadelphia.

Although in connection with his first employment it was necessary for him to acquire some efficiency in the burning of lead he became really active in the welding field only after joining the Badger organization. For the past eight years, however, he has been engaged in developments in the welding art in connection with the activities of his company and during the past six years has served continuously as an officer of the Boston Section of the Welding Society.



WRITE FOR CATALOG



We manufacture a complete line of resistance spot welders from 1/4 to 300 KVA for all types of welding. There is an EISLER WELDER for every purpose.

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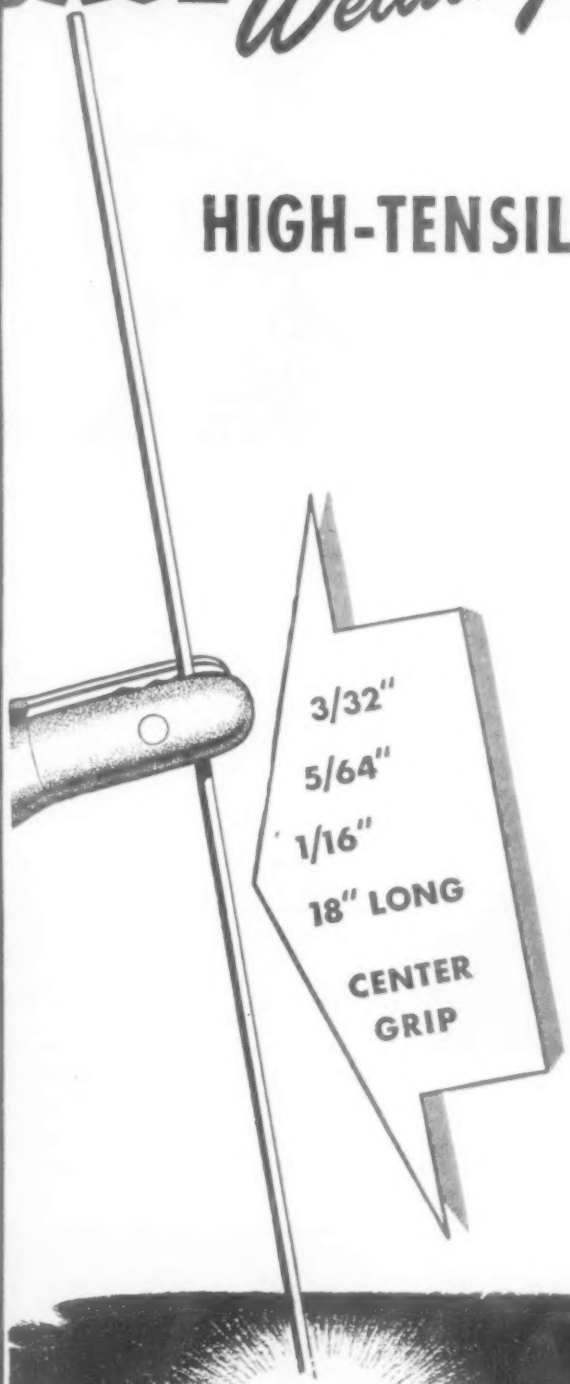
PAGE *Welding* ELECTRODES

HIGH-TENSILE "AF" NOW MADE IN "MIDGET" SIZES



• Light gauges of mild steel, which formerly had to be joined by means of some other method, can now be successfully welded. These new PAGE Hi-Tensile "AF" Electrodes, in midget sizes—3/32", 5/64", 1/16"—solve the problem.

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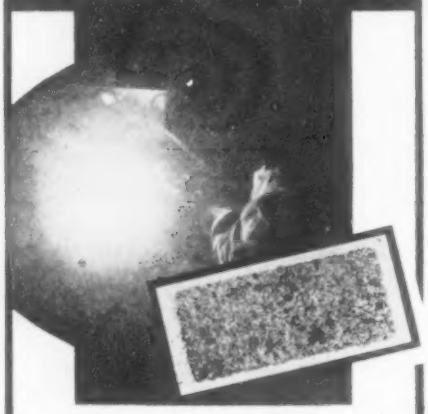

The un-retouched picture above was photographed through an uncoated cover glass on which is one hour's accumulation of weld spatter under average conditions.

This picture was photographed through a THERMACOTE plastic-coated cover lens that had been used, under identical conditions, for THREE WEEKS.

When welding with non-coated or lacquered cover glasses visibility decreases and eye-strain increases as weld spatter accumulates on the glass. Increased welding footage is the logical result of constantly clear vision through the use of THERMACOTE COVER LENSES.

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District No. 2—Mid-Eastern
William G. Thesinger

William G. Thesinger, who has been Director of Welding Research at Lukens Steel Company, Coatesville, Pa., since February 1941, has been appointed Assistant to Vice-President, it was announced today by D. S. Wolcott, Vice-President of the company. Dr. Thesinger will assist Mr. Wolcott in work connected with the manufacture, sale and application of special products such as clad steels.

Dr. Theisinger joined Lukens in August 1935 as Welding and Metallurgical Engineer and has specialized in the handling of technical matters involved in the application, fabrication and sale of the company's products.

Dr. Theisinger was born in April 1904, in Carlisle, Pa. After attending Harrisburg public schools, he became Assistant Chemist at Harrisburg Steel Corporation. In 1925 he became associated with the Board of Transportation of the City of New York in the development of welding inspection.

William G. Thesinger

In 1930, Dr. Theisinger matriculated at Harvard University receiving the degree of Bachelor of Science in 1934. That summer he served the Western Pipe and Steel Company as Consulting Engineer on high amperage, automatic welding. In 1935, after completion of post-graduate work at Harvard, he received the degree of Doctor of Science.

Dr. Thesinger is a member of the AMERICAN WELDING SOCIETY, the American Institute of Mining and Metallurgical Engineers, the American Branch of the Newcomen Society of England, the Franklin Institute and the Harvard Club of N.Y.

District No. 3—Southern
Sydney Swan

Mr. S. Swan is a graduate of the University of Michigan with a degree in Naval Architecture and Marine Engineering. He has been a surveyor to the American Bureau of Shipping for the past eight years and since 1943 has been a surveyor in charge of welding in the Gulf Coast district. In addition to membership in the AMERICAN WELDING SOCIETY, Mr. Swan is also a member of the Society of Naval Architects and Marine Engineers.

S. Swan

District No. 4—Central
B. L. Wise

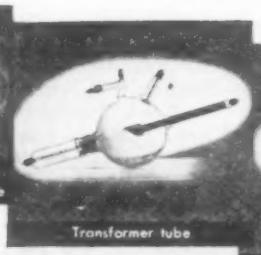
B. L. Wise is associated with The Federal Machine and Welder Co. as Assistant Manager of the Welder Division. He first became associated with resistance welding through the medium of electronics. His experience in this field started in 1922 with the Radio Tube Division of the Westinghouse Electric Corp., at East Pittsburgh while attending their Junior Engineering Course.

He later majored in electronics at the Pennsylvania State College, graduating in 1933 with a B.S. degree in Electrical Engineering. He is a member of the following honorary scholastic societies at the Pennsylvania State College: Tau Beta Pi, Eta Kappa Nu, Phi Kappa Phi, Sigma Pi Sigma and Pi Mu Epsilon.

After graduation he returned to Westinghouse as an Application Engineer for control equipment and electronic devices. It was through his work with electronic timers and contactors for resistance welding equipment that he became inter-

B. L. Wise

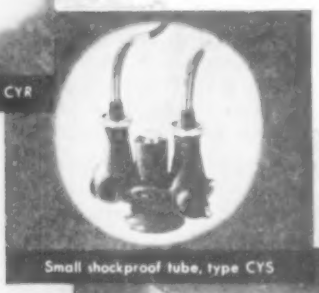
Cornell contact therapy tube



Transformer tube

Pyrex heavy anode bulb tube, type MR

Compact ray-proof tube, type CYR



Small shockproof tube, type CYS

Silver bearing long-life rotating target tube, type DX

Tube with beryllium window and hooded anode, 250 k. v., type IR

Tube with vacuum-tight beryllium window in envelope—the Diffraction Tube

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2,000,000 volt direct current precision radiographic tube, type VM

MACHLETT

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ested in resistance welding as an industry, later becoming Chief Electrical Engineer for The Federal Machine and Welder Co.

In this capacity, he was prominent in the development in aluminum spot welding equipment and processes. He has served on several committees of the AMERICAN WELDING SOCIETY and on numerous wartime committees. He is a member of the Ferrous Metallurgical Advisory Board on Welding of Armor and is currently Chairman of the Resistance Welding Subcommittee of the American Standards Association, Sectional Committee, C52—Electric Welding Apparatus. He is also a member of the A.I.E.E.

Many of the A.W.S. members know Mr. Wise through the talks he has delivered at various sectional meetings.

* * *

District No. 5—Mid-Western

R. E. McFarland

Mr. McFarland was born on March 23, 1888, at Wisconsin Rapids, Wis. His technical education was received at the University of Wisconsin. His entire professional career has been spent in connection with the Western Electric Co. He has been employed continuously at the Hawthorne Plant in Chicago for 31 years with the exception of 3 years in Tokyo, Japan, with what was then a subsidiary plant. His work has been of an engineering and supervisory nature having to do with Manufacturing Methods and Development with some 15 years in the welding field. Mr. McFarland has been active in the Welding Society since 1930. He was Chairman of the Chicago Section in 1938 and is at present Chairman of the 25th Anniversary Celebration Committee of that Section.

R. E. McFarland

* * *

District No. 7—Western

C. P. Sander

Clarence P. Sander was born in Seattle, Wash., Dec. 13, 1897. He attended Wilson's College and furthered his engineering studies at the University of Washington. He was Assistant General Manager of Pacific Car & Foundry Co., with plants at Portland, Ore., and Renton, Wash., for a number of years before joining Western Pipe & Steel Co. of California at Los Angeles in 1934 as General Superintendent, which position he still holds. He is a member of the Los Angeles Athletic Club and the Pacific Coast Club.

Mr. Sander has served on several committees with A.W.S., A.S.M., A.S.T.M.,

C. P. Sander

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Unusual opportunities in the postwar period will be available at Battelle Memorial Institute for qualified research men now in the services or engaged in war research.

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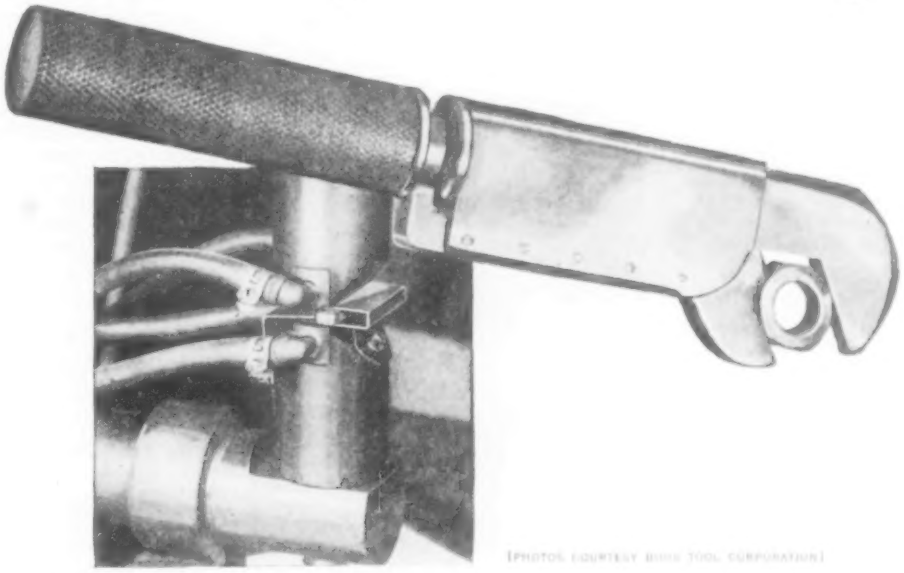
Welding More "Muscle" into the Jaw of this Wrench with MALLORY Projection Welding Dies



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SINCE the lower jaw bears most of the stress, the manufacturers of this adjustable angle wrench wanted to strengthen its lower jaw.

Mallory engineers quickly assisted in finding the answer. They recommended projection welding to fasten the lower jaw to the housing. Five small projections were stamped on each side of the housing, so that 10 welds would join jaw to housing in a single operation.

Result, according to the manufacturer, is that the fixed lower jaw—projection welded to the housing—is three times as strong as conventional designs! Mallory 3*Metal used for the projection welding dies assures high speed production, sound welds, and long runs.

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Here's a handbook you'll want . . . the improved, revised and expanded Mallory Resistance Welding Data Book (3rd Edition), containing the most complete information available on resistance welding methods, machines and materials. Free to those using resistance welding, when requested on company letterhead. Price to students, libraries and educational institutions: $2.50 per copy, postpaid. Board covers, 8½ x 11", 160 pages.

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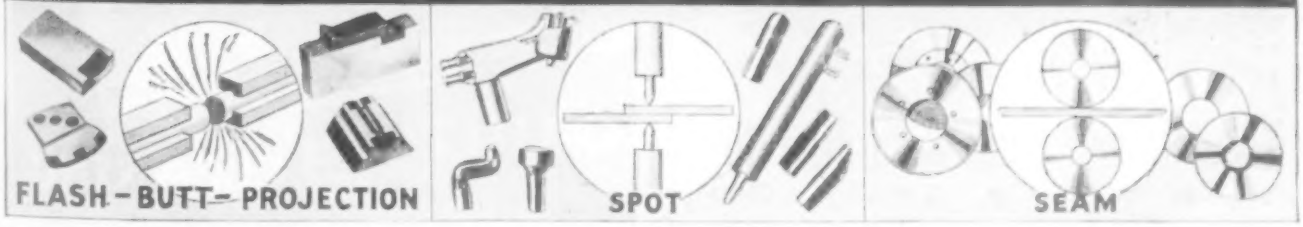
MALLORY Standard Resistance Welding Electrodes



A.P.I. and other technical organizations. He is a past chairman of the Los Angeles Chapter of the AMERICAN WELDING SOCIETY and has been a sustaining member of this SOCIETY since 1937. He has been in charge of many of the large welded jobs in the West.

* * *

A.W.S. BY-LAWS

The revised edition of the By-Laws, as published in the February WELDING JOURNAL, and additional amendments, noted on letter ballot, submitted for membership vote under date of June 1, 1945, now stand approved and will be incorporated in the By-Laws appearing in the 1946 Year Book.

SPANISH FOLDER

An envelope size folder printed in Spanish and entitled, "Comprobado en at Servico," describing Ampco-Trode coated aluminum bronze weldrod, has just been issued by Ampco Metal, Inc., Milwaukee 4, Wis.

The folder was designed to acquaint Spanish speaking welders with the advantages of this new aluminum bronze welding rod which has met with wide acceptance by the welding industry in America. It will be distributed largely by Latin-American jobbers and distributors of Ampco-Trode electrodes.

OXYGEN LANCING FACILITATES SCRAPPING OF HUGE CASTINGS

Since the oxygen lance can sever metal of practically any thickness, it is an effective trouble-shooter for metal-disposal problems. In many scrapping problems like that illustrated herewith, the oxygen lance is the only practical tool available.

A metal-working plant recently had to scrap a 100-ton steel casting. The cost of the usual method of disposing of scrap material used by this plant proved prohibitive for a job of this unusual size. It was decided that oxygen lancing was the only feasible means of cutting the huge piece. The results obtained by this method were so satisfactory that the company disposed of two other castings, each weighing 17½ tons, in the same way.

Courtesy The Linde Air Products Co.

A Huge 100-Ton Steel Casting Being Cut Up for Scrap with an Oxygen Lance. Three Completed Lance Slots Are Clearly Visible. At Some Points the Oxygen Lance Had to Cut Through Sections of Steel 5 Ft. Thick. Workmen Standing on the Casting Are Making a Supplemental Cut with a Cutting Machine

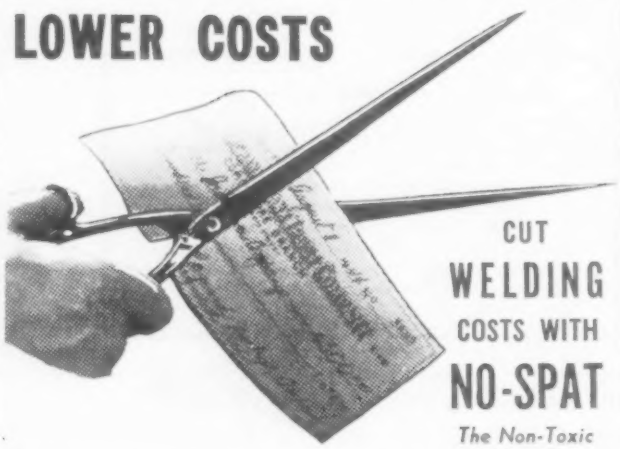
Despite snow and sub-zero temperatures, the lancing operation was begun immediately. Lancing was started about 28 in. below the top of the casting, which at this point was 5 ft. thick. After a hole had been lanced completely through, the cut was continued to the bottom of the casting. During this operation the lance was held at an angle to allow the slag formed from the cutting to run out of and away from the face of the cut. When the required number of these lance slots had been completed, the remaining web of material at the top of the casting was severed with a standard oxyacetylene cutting machine. The resulting slabs, measuring 3 x 6 x 5 ft., were then easily cut again with the oxyacetylene machine into suitable sizes for shipment.

THE LINCOLN ELECTRIC CO. OPENS NEW OFFICE

The Lincoln Electric Company announces the opening of a direct factory branch sales office in St. Louis.

The new branch, under the direction of Mr. B. J. Brugge as Welding Engineer and District Manager of Sales and Service, will be located at 4427 Manchester Ave., with telephone number Newsteak 6516.

RECONVERSION DEMANDS LOWER COSTS



CUT WELDING COSTS WITH NO-SPAT

The Non-Toxic Welding Fluid

NO-SPAT prevents adherence of spatter, saves cleaning time, cuts overall welding costs and protects metal against rust; maintains maximum welding strength; reduces fumes 30%; does NOT produce carbon monoxide gas. Inexpensive, ready to use.

SAVES TIME SAVES MONEY SAVES LABOR

Send for FREE SAMPLE and detailed engineering test bulletin.

The Midland Paint & Varnish Co.

9126 RENO AVENUE CLEVELAND 5, OHIO

Is this YOUR Cleaning Problem?
Preparing Welded Steel Surfaces for Painting
After resistance, gas or arc welding of steel surfaces, a prime requisite for effective paint adhesion is a clean, GREASE-FREE conditioned surface.
Various specialized Oakite acid and alkaline type materials are available for this essential surface preparation work. ALL provide the CLEAN surface that assures firm, tenacious grippage of paint or similar organic finishes.
If you are experiencing trouble on this type of work, let us help you correct it. Oakite Technical Service is FREE for the asking.
OAKITE PRODUCTS, INC., 18E Thames St., NEW YORK 6, N.Y.
Technical Service Representatives Conveniently Located in All Principal Cities of the United States and Canada
OAKITE
MATERIALS - METHODS - SERVICE
Keep Buying Bonds
CLEANING
FOR EVERY CLEANING REQUIREMENT

NEW STUDY THROWS LIGHT ON IMPORTANCE OF FERRO MANGANESE PARTICLE SIZE

Prolonged and inconclusive controversy over the influence, if any, of particle size on manganese transfer, especially from high carbon ferro manganese, led us to make an independent check.

Tests were run with stainless steel electrodes*. The percentage of FeMn in the coating was the same in each. The only variable was the size granulation.

It was found that the manganese pick-up efficiency increased as the particle size increased and vice versa. One logical explanation is that smaller particle sizes expose greater surface per unit of weight. Complete oxidation is faster, causing manganese build-up in the slag rather than the weld metal.

Commercial checks substantiate these data.

It is interesting to note (Sample 2) that the presence of ferro silicon increases manganese pick-up.

Further current studies in our laboratories indicate that particle size gradations in the coarsest range possible increase manganese pick-up by at least 8%.

*Further work is being done on mild steel electrodes.

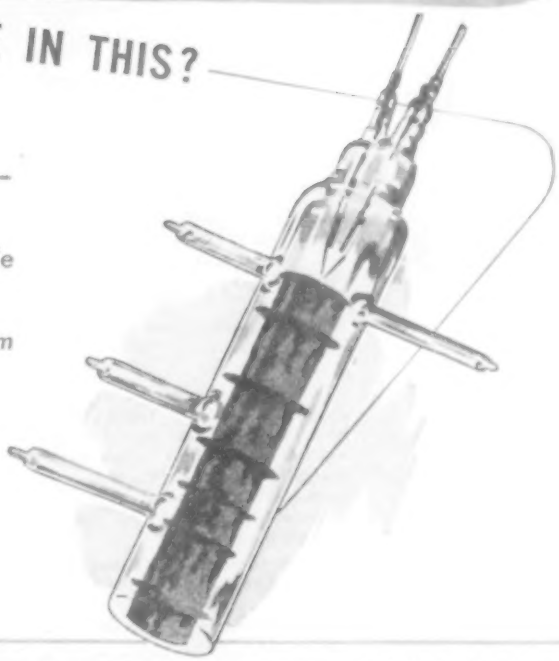
% MANGANESE RECOVERY IN WELD METAL VS. PARTICLE SIZE

Sample No.	Fraction	% FeMn in Coating	% FeSi in Coating	% Mn in Weld	% Recovery
1	Standard granulation	16	0	1.29	37.8
2	Standard granulation	16	6	1.91	56.0
3	40 x 100 Mesh	16	0	1.52	44.6
4	100 x 200 Mesh	16	0	1.27	37.2
5	200 x 325 Mesh	16	0	1.20	35.2
6	Minus 325 Mesh	16	0	0.99	29.1

(Core Wire = 0.42% Mn)

CAN YOU SEE YOUR FUTURE IN THIS?

Foote researchers not only produce pure ductile zirconium by electrolytic deposition—in tubes like this—but even fabricate the vacuum tubes used in the process. For many an industry there is a forseeable future with ductile zirconium. For almost all industry Foote chemicals, ores, minerals, alloys and custom grinding have an important mission.



Foote
MINERAL COMPANY
A Step Ahead in Industrial Ores and Chemicals

PHILADELPHIA • ASBESTOS • EXTON, PENNSYLVANIA
Home Office: 1611 SUMMER STREET, PHILADELPHIA 3, PA.
West Coast Repr.: Griffin Chemical Co., San Francisco, Calif.

HEAKIN PROMOTED

H. L. Heakin has been named a district representative for the A. O. Smith Corp., covering northern California, Utah and Nevada, and will establish headquarters soon in San Francisco, it has been announced by Ray E. Howes, administrator of the Los Angeles district of the company. Mr. Heakin will handle all of the company's lines, which include pressure vessels, steel storage tanks, line pipe, oil well casing, railroad equipment, electrodes and consumer goods such a storage water heaters and domestic stokers. Mr. Heakin is a graduate of the University of Michigan and has done postgraduate work at Stanford University and the University of California. He has had previous connections with the Worthington Pump and Machinery Corp., the Pacific Foundry Co., Domestic Engineering Corp., Union Switch and Signal Co., and Westinghouse Air Brake Co. He is a member of the AMERICAN WELDING SOCIETY.

HORTONSPHEROIDS

The Chicago Bridge & Iron Co., Chicago, Ill., announces the publication of a new 9-page leaflet, "The Hortonspheroid," which describes the reduction of evaporation losses from volatile liquids by storing them under pressure in Hortonspheriods. The reduction of filling, boiling and breathing losses are discussed together with a description of the fittings included with Hortonspheroids. Gauging methods including theoretical gage tables, tank strappings and water calibration are described. A copy of the booklet will be sent on request.

VICTOR CATALOG

The new Victor publication (Form 52) just issued is devoted entirely to Victor Hand and Machine Cutting Torches and Tips. It is a striking brochure of 40 pages, attractively printed in colors, and gives full information on the hand-cutting torches, various types of cutting attachments, machine cutting torches, underwater cutting torches and the various auxiliary equipment that are needed in successful cutting operations. This catalog represents the products of the company which has devoted three decades to designing and producing gas welding and flame cutting torches. Copy of this bulletin may be obtained from Victor Equipment Co., 844-54 Folsom St., San Francisco, Calif.

SULLIVAN-CASSIMUS CO. OFFICE

Sullivan-Cassimus Co., with offices in San Francisco and Los Angeles, are pleased to announce the opening of an office in Seattle at 518 E. Pike St. This office is to be under the management of Carl C. Torell.

Sullivan-Cassimus Co. is the Pacific Coast representative of The Federal Machine & Welder Co. of Warren, Ohio, and because of the increased use and demand for resistance-welding equipment this new office will be better able to serve its large number of users.

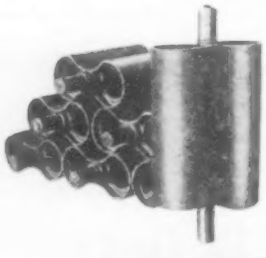
EIGHTH EDITION LINCOLN WELDING HANDBOOK

Procedure Handbook of Arc Welding Design and Practice, 8th ed., published by The Lincoln Electric Co., Cleveland, Ohio; 1312 pages, 6 x 9 inches, 1647 illustrations, including photos and drawings; cover, semiflexible simulated leather, gold embossed; price postpaid United States $1.50 per copy, elsewhere $2.00 per copy.

Entirely revised to include the latest data on new arc-welding methods and equipment, the eighth edition of the *Procedure Handbook of Arc Welding Design and Practice* has just been announced by the publishers.

In addition to standard data on welding symbols, speeds and costs, characteristics of metals, preheating, stress relieving, approach to welded design and other pertinent information, the newly revised Handbook includes sixteen new subjects such as:

New cost tables
New welding techniques
Mathematical calculations for new welded designed structures
Latest steel specifications on S.A.E. and A.I.S.I., including National Emergency Steels, etc.
Underwater cutting
Shop ventilation
Maintenance of welding equipment
Methods of testing



IN REGULAR PRODUCTION AT UNITED WELDING

WELDMENTS SINCE 1913

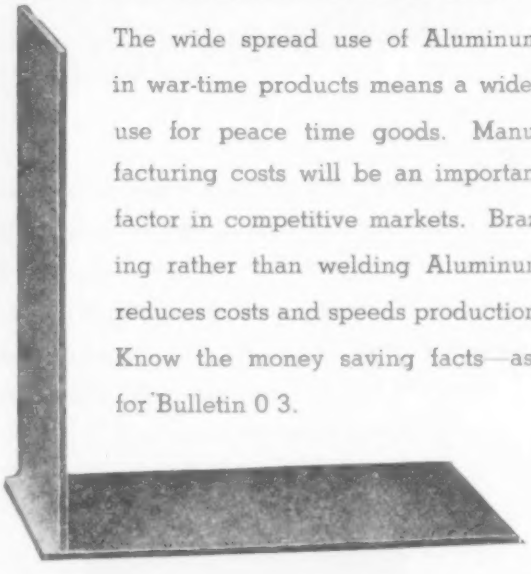
Blower impellers, like those above . . . field rings like those below . . . are today regular "grist for our mill."

You, no doubt, have or soon will have, products to market. Those products may be of a design that would gain through welded construction . . . for style . . . for strength . . . for lightness . . . to make them less costly to produce. If so, our engineers and our facilities can serve you to advantage.

Let us look at your drawings. Confidential of course. Get our quotations.

THE UNITED WELDING CO.
MIDDLETOWN, OHIO
WELDING FABRICATORS OF MODERN DESIGNS

BRAZE ALUMINUM POST-WAR PRODUCTS



The wide spread use of Aluminum in war-time products means a wider use for peace time goods. Manufacturing costs will be an important factor in competitive markets. Brazing rather than welding Aluminum reduces costs and speeds production. Know the money saving facts—ask for Bulletin 0 3.

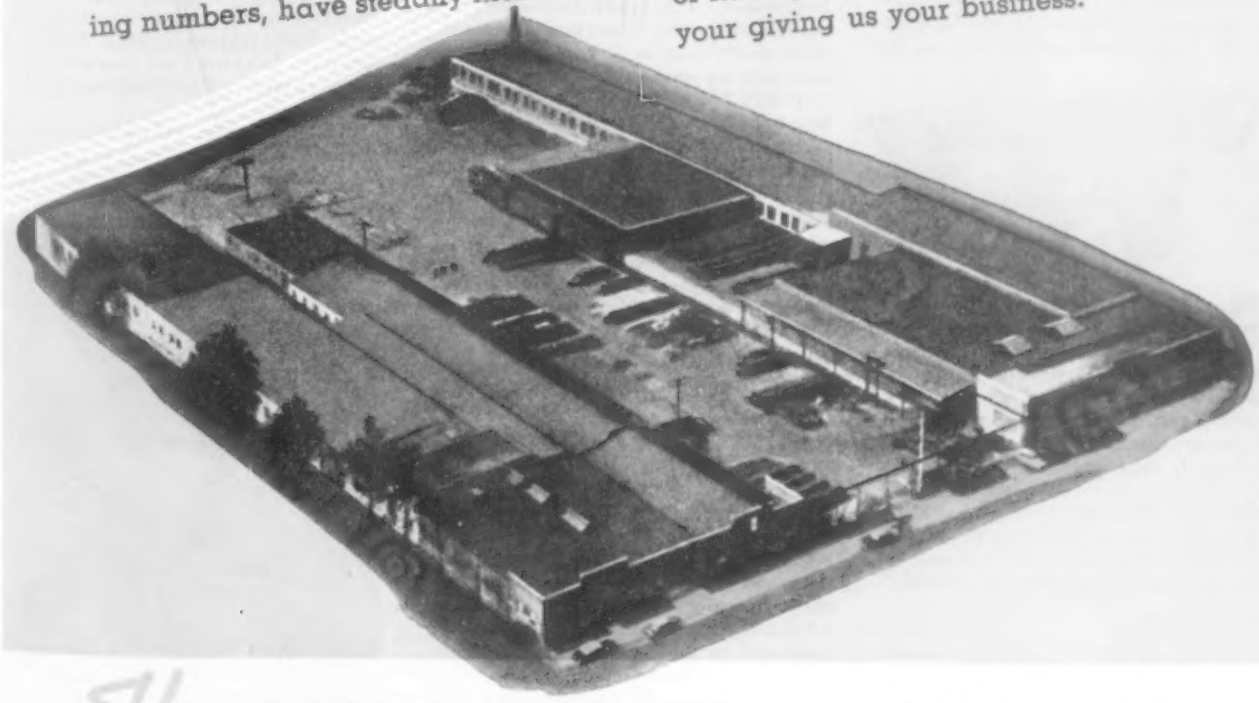
KRE-CO MULTICHEMIC FLUX
DIVISION OF
CHARLES W. KRIEG CO.
52-60 Dickerson St. Newark 4, N.J.

Thank you, Customers,

you've brought us a long way!

From ten employees to three hundred . . . from a shed to a great modern plant—that's how we have grown since our beginning in 1919. And we've grown because you, in increasing numbers, have steadily increased your demands for our products.

We have one means to show our appreciation—our assurance that we shall not only maintain, but strive to improve wherever possible, the quality of Raco products that has warranted your giving us your business.



The REID-AVERY COMPANY

INCORPORATED

DUNDALK • BALTIMORE 22 • MARYLAND

SINCE 1919 PRODUCERS OF ARC WELDING ELECTRODES AND WELDING RODS

Filler metal specifications for arc welding electrodes

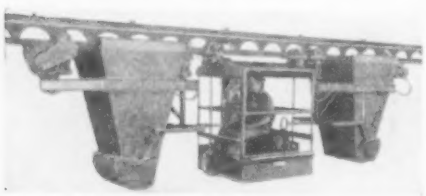
The principal sections of the new *Procedure Handbook*, 8th ed. cover the following subjects:

Part I—Welding Methods and Equipment (26 pages)
Part II—Technique of Welding (126 pages)
Part III—Procedures, Speeds and Costs (154 pages)
Part IV—Weld Metal and Methods of Testing (32 pages)
Part V—Weldability of Metals (130 pages)
Part VI—Welded Steel Construction—Machine Design (226 pages)
Part VII—Designing of Arc-Welded Structures (316 pages)
Part VIII—Typical Applications of Arc Welding in Manufacturing, Construction and Maintenance (214 pages)

CAB BUCKET CARRIER

A new motor-driven cab-operated double bucket carrier has been developed by The Cleveland Tramrail Division of The Cleveland Crane & Engineering Co., Wickliffe, Ohio, for the transportation of dry bulk materials.

The operation of the carrier and the opening and closing of the bucket gates are handled by the cab operator who sits on a swivel chair enabling him to work in the direction of either bucket. A single variable speed drum controller is located on one side of the cab, but two foot brakes are provided, one at either end so that one is always in convenient reach of the operator regardless of which direction he is operating the carrier. Push-pull levers for opening the bucket gates extend into the cab



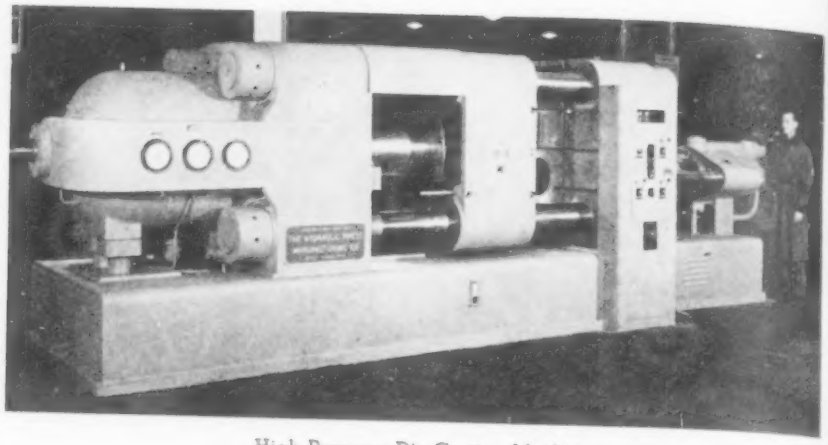
and permit emptying the materials in any amounts and at any rate desired.

The unit illustrated has two 25-cu. ft. buckets and is designed for carrying a total load of two tons. Other size Cleveland Tramrail carriers can be supplied, however. The buckets are designed and located with reference to the tramrail arch beam rail, so that they may be easily filled from overhead bins without interference or spillage.

The carrier is provided with two motorized travel drives, one at each end, and operates at speeds up to 600 ft. per minute.

HIGH-PRESSURE DIE-CASTING MACHINE

The Hydraulic Press Manufacturing Co., Mount Gilead, Ohio, announces the completion of one of the world's largest high-pressure die-casting machines. This massive "all-hydraulic" machine is designed to cast 14.88 lb. of aluminum alloy per "shot" at an injection pressure of 25,000 psi. This weight represents a casting volume of 154½ cu. in.



High Pressure Die-Casting Machine

For one to realize the magnitude of this new H-P-M die-casting machine, compare its injection capacity of 14.88 lb. with that of 2.4 lb., the maximum 25,000 psi. injection capacity of the largest standard existing high-pressure machine. A majority of high-pressure aluminum die castings are produced with injection pressures ranging from 10,000 to 12,000 psi. If such pressures prove satisfactory for extremely large parts, it is quite possible that aluminum castings weighing 30 lb. or more can be produced with this revolutionary H-P-M die-casting machine. The development of this huge H-P-M die-casting machine may revolutionize the production of large light metal alloy parts, since all of the advantages of high-pressure die casting can now be obtained. Principally these advantages are the ability to produce interchangeable, high-quality part at a very high hourly rate, and to shape them so precisely as to reduce finishing operations to an absolute minimum.

The base of the 1000-ton die casting machine in question is fabricated by welding. The long straight seams of this member were welded automatically while shorter welds were made manually. Part of the base serves as an oil reservoir. The prevailing plate thickness is ¾ in. and the structure is well ribbed to support the weight of the mold clamp and the injection unit.

A BIBLIOGRAPHY ON CUTTING OF METALS

This Bibliography which has been prepared by Professor O. W. Boston combines Parts 1 and 2 published in 1931 and 1935, respectively, with 3500 additional items. Arranged alphabetically by authors, and chronologically by years, the 4124 annotated references in this work provide those interested in the subject with a comprehensive list of the most important articles on metal cutting, including shaping, grinding, analysis and treatment of the various cutting tools; turning; milling; drilling; planing; shaping; broaching; reaming; etc., from 1864 to 1943, inclusive. Specifically, there are subjects on carbon steel tools; high-speed steel tools; cast alloy steel tools; cemented carbide tools; welded-tip tools; diamond tools; chromium-plated tools; nitrided tools; on power energy, or force; dynamometers; tool life; tool wear; cutting temperatures; speed, feed and depth of cut; chip formation; finish; cutting fluids; material machinability properties; general, not otherwise specified. Author and subject indexes are also included.

Published June 1945. 561 pages, 4124 references, flexible leather binding. Price $6.50.

TIEDEMANN MADE PRESIDENT

A. Carl Tiedemann, long affiliated with Detroit's Automotive Industry in a manufacturing and sales capacity, was recently elected President of the Dockson Corp., 3839 Wabash, Detroit—Michigan's largest manufacturer of welding and safety equipment and supplies. Mr. Tiedemann joined the Dockson Corp. less than a year ago as Executive Vice-President and General Manager.

He states that an ambitious program of expansion for his Company is planned to meet anticipated peacetime demands for its products.

A. Carl Tiedemann

Mr. Tiedemann is a sustaining member of the AMERICAN WELDING SOCIETY.

Scrap Heap into "Treasure Trove"

How welding — aided by RADIOGRAPHY — turned $840 worth of scrap into $35,000 worth of usable castings

Almost as dramatic as a Yukon "gold strike" is this case history of welding and radiography teaming up to increase production and rescue $35,000 worth of critical castings from the scrap pile.

The castings were costly, complicated to cast, demanded the most precise technic. Despite all precautions, flaws proved unavoidable . . . deliveries fell behind schedule.

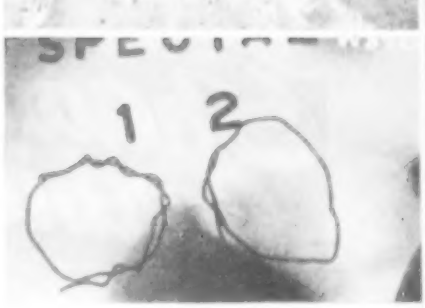
Could these castings be reclaimed? Welding offered an obvious solution to the problem . . . with radiography called in for a strong "assist."

Internal irregularities in the castings were located by radiography . . . the welded repairs were made and x-rayed. Study of the radiographs showed the welds to be sound and the castings acceptable. The 350 castings which were thus salvaged each month brought deliveries up to schedule—with a monthly saving of thousands of dollars.

To the welder, this case is of prime importance . . . shows how industrial x-ray is his natural partner . . . how it opens new and profitable fields of business. Radiography's ability to examine internal structures guides welders to new fabricating methods. Why not investigate its advantages now? See your local x-ray equipment dealer.

Investigation discloses irregularity. A flaw typical of those which slowed the foundry's deliveries on these complex housings.

Welding repairs the condition . . . BUT: Is the weld sound, is penetration satisfactory and metal well fused? Will the casting meet inspection requirements?



Radiography approves the repair: "Yes," says this radiograph—welding has made the rejected casting sound, sturdy, acceptable, and ready to use.

EASTMAN KODAK COMPANY, *X-ray Division*, Rochester 4, N. Y.

RADIOGRAPHY

ANALYZES . . . INSTRUCTS . . . CORRECTS . . . IMPROVES

Kodak

HEAVY-DUTY MARINE MACHINERY

A Unionmelt welding installation used by a manufacturer of heavy marine propulsion equipment has contributed greatly to the speedy production of such machinery. This installation is typical of many for heavy-duty fabrication jobs being done by this process—jobs calling for high-quality welds to meet the rigid specifications of the American Bureau of Shipping as well as the A.S.M.E.

Shown here (Fig. 1) is a 12-ft. marine turbine reduction gear under construction. The heavy stiffening webs on each side of the gear are being fillet welded to the rim by the Unionmelt apparatus to the right of the operator. In this installation a Type UE-21 welding machine, mounted on a cantilever platform, is used as a stationary unit while the work is revolved by the welding positioner. The reel in the foreground supplies the welding rod from 150-lb. coils to the machine. Each fillet weld, measuring about $1^1/_8$ in. across the face and 36 ft. in length, is made in only one pass, with deep and complete penetration. Welding at the high speed afforded by the use of the Unionmelt process allows but little heat to be dissipated into the zones adjacent to the weld, thereby minimizing distortion and stress in the structure. As can be seen from the unretouched close-up (Fig. 2), the weld is clean and uniform in appearance, and no machining or spatter removal will be necessary before putting it in service.

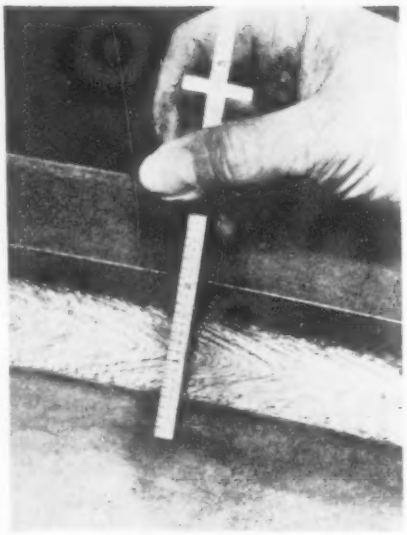


Fig. 2—Close-up of Face of Fillet Weld Made by the Unionmelt Process

Since the welding action is fully automatic, the quality of the weld does not depend on the welding skill of the operator. This eliminates one of the greatest variables common to other welding processes. The welding is done beneath a layer of special granulated material with no visible arc or flame; this reduces operator fatigue by making it unnecessary to wear a welding shield or gloves. The opeartor, with a vacuum "melt recovery" machine, is removing the unfused granulated flux which can be re-used.

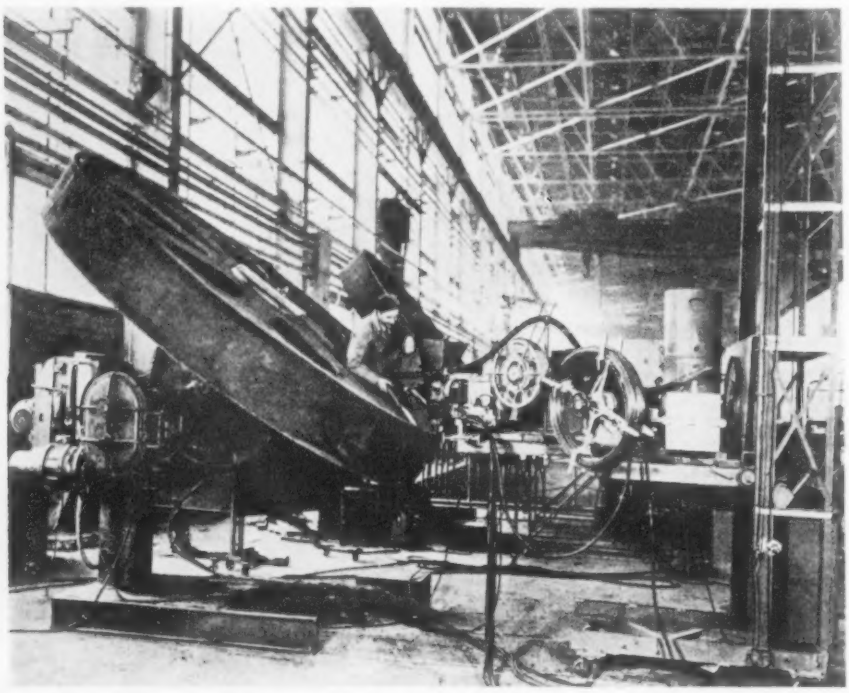


Fig. 1—The Huge Side Webs of This 12-Ft. Marine Turbine Reduction Gear Are Being Welded Into Place by the Unionmelt Electric Welding Process. Operator Is Removing the Unfused Granulated "Flux" for Re-use

WELDED WIRE PRODUCTS FOR PRECISE ELECTRICAL EQUIPMENT

Welds of multisection wire products made of tungsten, copper clad steel, copper, nickel and copper and nickel alloys are mass produced in sections ranging from 0.0005 in. to 0.1280 in. diameter by the Warren, Pa., plant of Sylvania Electric Products, Inc. These welds are suitable for leads, pins and mounts used in incandescent and fluorescent lamps; electron tubes; evacuated and gas-filled switches and many special, hermetically sealed electrical devices. Tungsten, nickel and copper clad wire products with or without

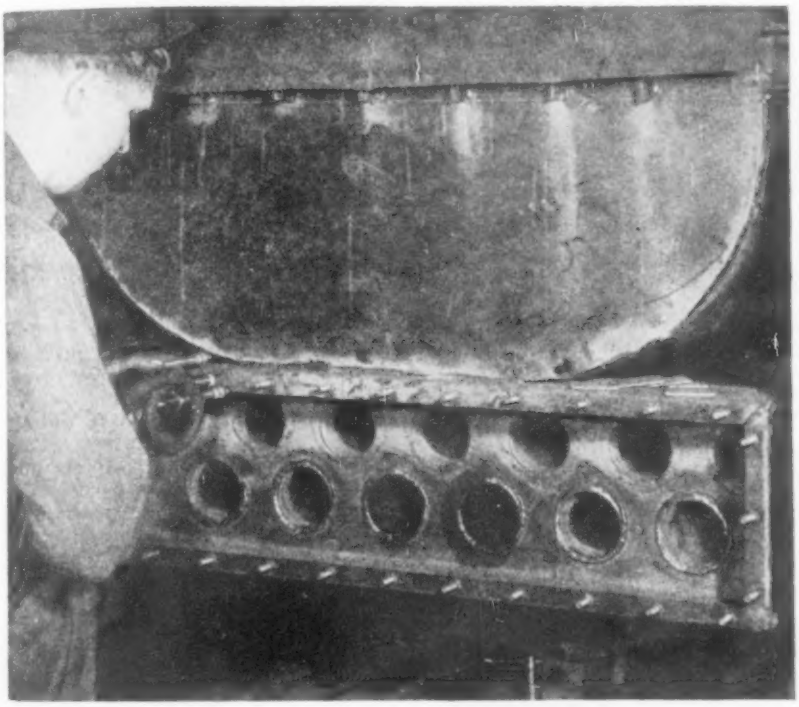
Time Counts—
Gas cut and Weld with
Shawinigan Carbide

SHAWINIGAN

SHAWINIGAN PRODUCTS CORPORATION
EMPIRE STATE BUILDING, NEW YORK 1, N.Y.

TIP CLEANING **DRILLS**
Mounted in Knurled
BRASS *Handled*
•
LARGE STOCK
PROMPT DELIVERY
NO RATING REQUIRED
•
DISTRIBUTORS WANTED
NEW MEXICO STEEL CO.
Box 691, Albuquerque, N. M.

Nelson *Automatic* Stud Welding saves time and material!



Nelson Stud Welding saves time and material because it eliminates drilling holes and tapping to secure studs. In *less than a second* studs from ⅜" to ¾" diameter are secured. Automatic operation and accurate arc timing control produce complete fusion of the stud to metal. Operators are trained quickly and produce consistent results.

Thousands of stud welders are now used by more than 750 industrial plants and shipyards . . . because 500 to 1000 studs per operator can be secured per shift.

For rapid *precision* production of stud welded parts single and multiple stud welding units are available which weld one or more studs of various sizes at the rate of 20 to 30 welds per minute.

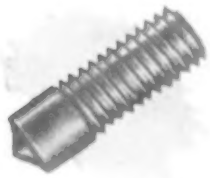
Write today for complete information on this time and material-saving equipment:

NELSON SPECIALTY
WELDING EQUIPMENT CORP.

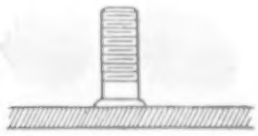
Dept. H, 440 Peralta Avenue
San Leandro, California

Eastern Representative: Camden Stud Welding Corp., 1416 South Sixth Street, Camden, N. J.

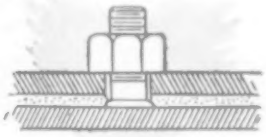
HOW NELSON STUDS
ELIMINATE DRILLING
AND TAPPING



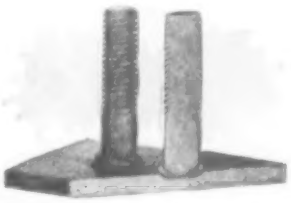
After layout and center-punching a stud is placed in the gun chuck. The pointed end is located in the punch mark and the trigger pulled. Instantly the arc flashes and the weld is made. The operator loads again and proceeds to the next weld.



Complete fusion between stud and metal results . . . drilling and tapping operations have been eliminated.



Cover and gasket fit easily and a neater result is obtained. One gun welds any diameter stud — a standard welding machine is used.



Cutaway of typical stud weld. Etched with Nital to show penetration.

welds to as many as four other metals may be supplied surfaced for direct bonding with glass. All sections are electrically welded to assure good electrical and mechanical design. Facilities include those for product and tool design, tool production and modern production equipment to assure uniform, high-quality products to close specifications. Contact pins for radio tubes, plug-in coils and similar products are also fabricated from solid nickel or tungsten rod with ground or rolled tips and cut to exact lengths for leads, mounts and glass seals. Inquiries for these or similar products are invited. Address Sylvania Electric Products Inc., Warren, Pa.

PRIZE ILLUSTRATION

The accompanying photograph was taken from the front cover of the July issue of *Water Tower*, a magazine published by the Chicago Bridge and Iron Co. It was made by R. V. Schneider of the Chicago drafting room. It shows the welding of a curved section of steel pipe in the Chicago plant of the company. Schneider entered this photo in the Jackson Park Camera Club's competition in May 1945, where it took top honors by being selected as the "Print of the Month." It has been chosen as the Club's "Print of the Year."

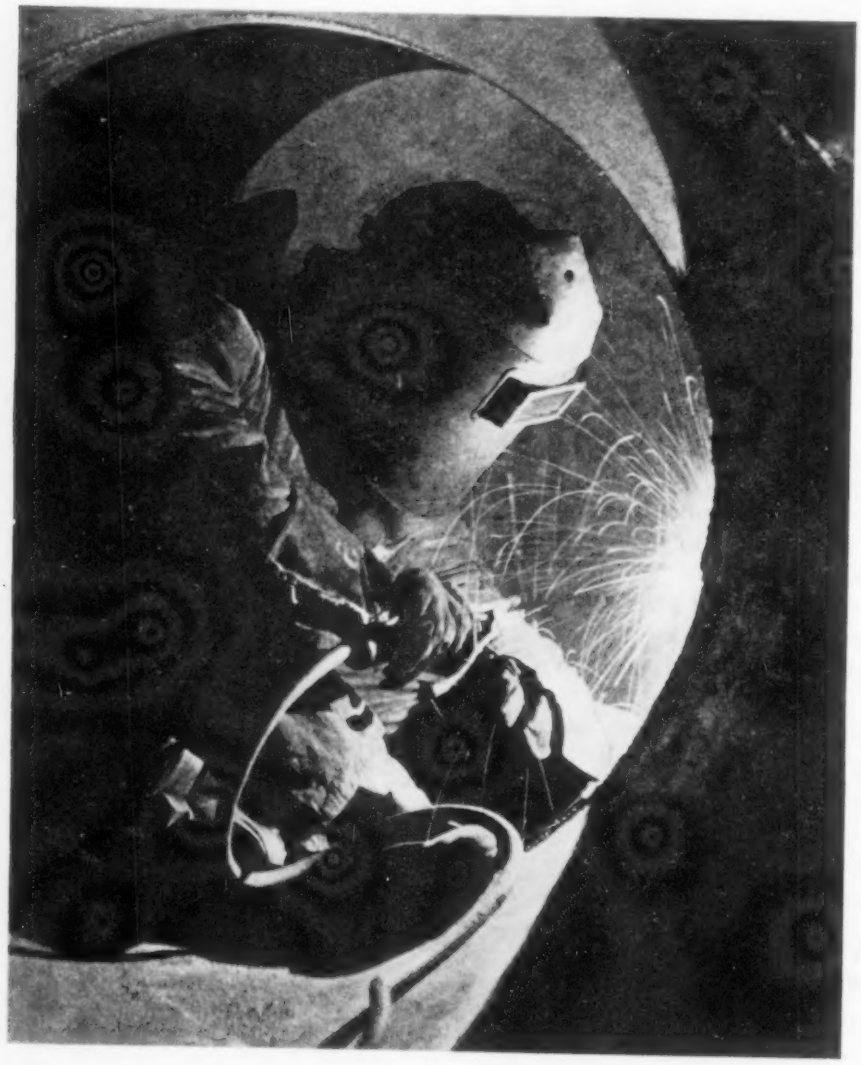
The U. S. S. *Intrepid* Under Fire. Official U. S. Navy Photograph

A FOUR-TIME VICTIM OF JAP AIR ACTION

Four times the U.S.S. *Intrepid* has been battered into flames by Jap air action, and four times the big Essex-class carrier has returned to rain more destruction upon the enemy. In 15 months of combat operation, the Intrepid's guns and planes have sunk 80 ships and destroyed 650 aircraft. that she is the most frequently hit carrier in the U. S. Navy makes this record even more incredible. The Intrepid was first hit at Truk during the initial raids on this stronghold, February 16, 1944. Back in action off Luzon, October 29th, the flattop took one of the first successful Jap suicide hits. Again on November 25th, two Jap kamikazes rocketed into her flight deck to turn the big carrier into a blasing gasoline-fed inferno. Even though "abandoning" seemed the only logical answer, the crew battled heroically for two-and-one-half hours to save their burning ship. In action again for the Okinawa campaign, Intrepid pilots helped send the 45,000-ton battleship *Yamato* to the bottom. Then on April 16th, while her airmen were carrying the war to Japan's home islands, the Intrepid was hit for a fourth time by one of five attacking suicide planes. Her battle damage repaired for a fourth time, the Intrepid lives up to its proud name. The "ghost" of many Jap "sinkings" has long since rejoined the fleet.

On April 16th a Jap suicide plane loaded with a bomb sent the U.S.S. *Intrepid* into flames again. An experienced crew saved the ship again that day. As smoke rises from the carrier break out fire hoses and other equipment to battle the flames. This attack sent the *Intrepid* back to the yard for a fourth time in 15 months, but now better than ever, the *Intrepid* has returned to the Pacific to deal out more destruction to the enemy.

A 15 ft. x 20 ft. temporary patch was welded on the flight deck of the SS *Intrepid* in only forty-five minutes, which enabled planes in the air to land on the carrier before they ran out of fuel and were forced into the sea.



"J. G. . . .

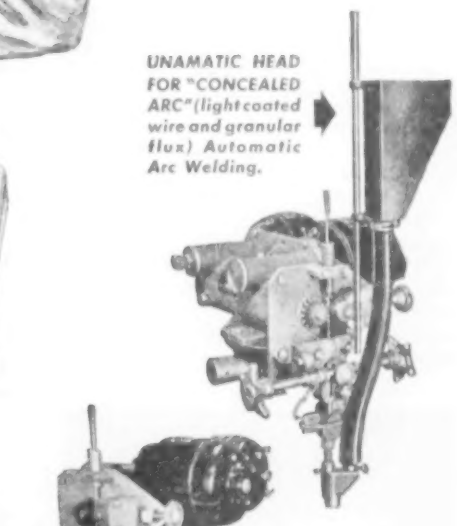
UNAMATIC WELDING

MIGHT BE OUR ANSWER TO FASTER PRODUCTION, LOWER COSTS...LET'S LOOK INTO IT."

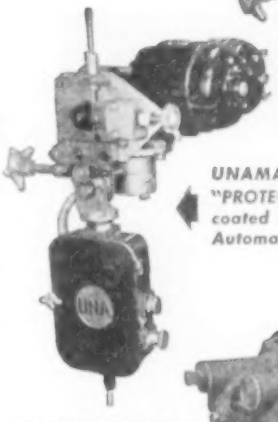
Alert, cost-minded factory men, in all types of companies are making this recommendation to the management because they have been checking up on Unamatic Arc Welding and see its advantages.

Many plants have found that Unamatic Arc Welding speeds production up to 300% and cuts materials costs as much as 15%. With Unamatic processes there is no problem of "fatigue periods" usually between 11 to 12 a. m. and 4 to 5 p. m., and the resulting high percentage of rejected work.

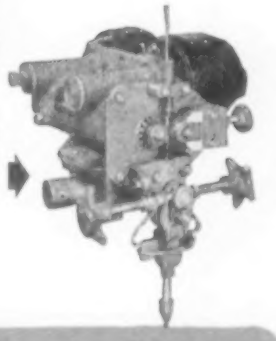
Perhaps you would like to have one of our field engineers survey your plant to determine the advantages you may gain by employing the Unamatic processes. Write and we shall be glad to arrange it — without obligation to you, of course.



UNAMATIC HEAD FOR "CONCEALED ARC" (light coated wire and granular flux) Automatic Arc Welding.

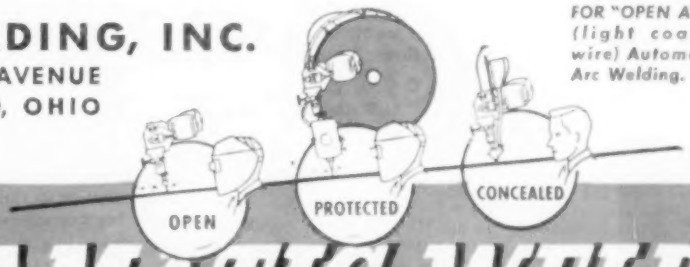


UNAMATIC HEAD FOR "PROTECTED ARC" (light coated wire and tape), Automatic Arc Welding.



UNAMATIC HEAD FOR "OPEN ARC" (light coated wire) Automatic Arc Welding.

UNA WELDING, INC.
1615 COLLAMER AVENUE
CLEVELAND 10, OHIO



UNAMATIC WELDING

NATURALLY UNAMATIC EQUIPMENT WORKS BEST WITH UNAMATIC WIRE AND FLUXES

NEW PRODUCTS

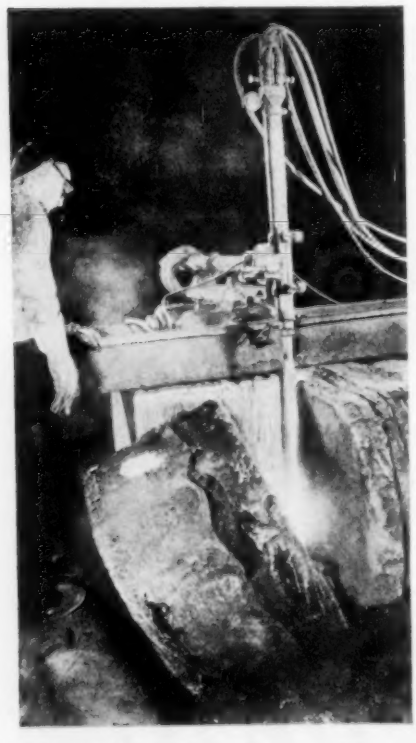
The Society assumes no responsibility for the validity of claims in this Section

HEAVY-DUTY MACHINE-CUTTING BLOWPIPE

A new heavy-duty, oxyacetylene cutting blowpipe, the Oxweld C-45 machine-cutting blowpipe, has been developed by The Linde Air Products Co., Unit of Union Carbide and Carbon Corp. This new blowpipe, which cuts steel ranging in thickness from 16 in. to 50 in., is particularly suited for hot top cutting, ingot slitting, riser cutting, cutting large forgings and scrap cutting in many applications where the oxygen lance was formerly required.

The C-45 is water cooled and is intended to be mounted on a heavy-duty, straight-line cutting machine such as the new Oxweld CM-37 machine or the familiar Oxweld CM-21 cutting machine. A 50-lb. gage is attached to the blowpipe body for checking cutting-oxygen pressures which are unusually low—never over 35 psi. The C-45 blowpipe is designed for operating with medium-pressure acetylene and will operate satisfactorily on a generator or a manifold having a minimum hourly capacity of 500 cu. ft. of acetylene. Unless cutting oxygen is supplied from a pipe line, at least 10 cylinders should be manifolded to provide sufficient capacity. In shops where steel over 18 in. thick must be cut frequently, the C-45 blowpipe provides a tool for making these cuts quickly and economically.

Also available is the Oxweld C-45 blowpipe holder, which has been designed especially for this blowpipe. It provides ease, accuracy and stability in making vertical and angular adjustments. Vertical adjustment is obtained by turning a ball crank which operates a worm and gear that meshes with the blowpipe rack. A total angular adjustment of 135° can be obtained in the plane of the cut.



The C-45 Is Shown Here Cutting a Chrome-Nickel-Molybdenum Hot Top to Charging Box Size. The Cut Through a 29-In. Thick Section Is Made at 3 In. per Minute

ELECTRODE FOR HIGH TENSILE STEELS

A new shielded arc electrode for groove butt joints and welding horizontal or flat fillets in the higher tensile steels, such as A.S.T.M. A-212, has just been announced by The Lincoln Electric Co., Cleveland, Ohio.

Designated as "Fleetweld 11-HT," it has outstanding characteristics not found in previous rods designed for welding steels of this type

Exhaustive field tests have shown that the quality of groove butt joints made with this new electrode are exceptionally good and free of porosity. Fillet welds made with "Fleetweld 11-HT" are extremely smooth with a flat face. The electrode has a remarkably low spatter loss and welds are produced with a steady arc and are free from undercut.

Speeds are remarkably good and low-alloy, high-tensile steels can be welded as easily and as fast with "Fleetweld 11-HT" as mild steels can be welded with the ordinary E-6020 type of electrode.

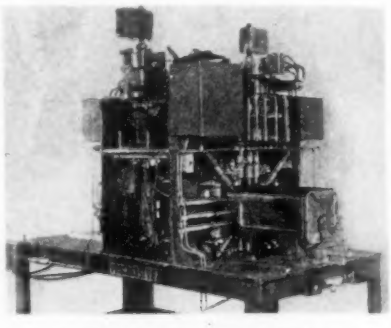
All weld metal specimens of "Fleetweld 11-H" test as follows:

	As-Welded	Stress Relieved at 1200° F.
Tensile strength, psi.	75,000–80,000	72,000–76,000
Yield stength, psi.	59,000–62,000	57,000–61,000
Ductility (elongation in 2 in.), %	19–23	25–30

The electrode may be used with either alternating current or direct current and if direct current is used, the electrode should be negative. The new electrode conforms to AMERICAN WELDING SOCIETY specifications E-7020 and/or E-7030, and is available in $^{3}/_{16}$-in. and $^{1}/_{4}$-in. diameter sizes, 18 in. long. It is shipped in standard containers of 50 lb. each.

DUAL HYDROMATIC SPEEDS CONTAINER ASSEMBLY

Typical of the many wartime developments which may well reduce postwar production costs is this dual hydromatic multiple spot welder built by Progressive Welder Co., 3050 E. Outer Drive, Detroit 12, Mich., for assembly of ammunition boxes. Combining several operations in one, this dual welder (there is a duplicate welding station in back of the vertical panel) permitted output of some 220 containers per hour, in a minimum of floor space.



Dual Hydromatic Spot Welder

Economy of equipment is secured by using only a single transformer for both welding stations and using standardized parts for the various "guns." Simple air shuttling fixtures reduce loading time. These have interlocking controls so that one operator welds while the other one is loading. The container being fabricated in this view is a storage and shipping unit for 40-mm. ammunition.

METRO POSITIONER

The purpose of the new model S Metro Positioner is to simplify the tilting of work during various assembly operations, by permitting the angle of tilt to be adjusted almost immediately and without the necessity of stopping work to manipulate wrench.

In principle, the existing vise or fixture is bolted, or otherwise secured, to the "Place Plate" of the Metro Positioner. This plate is integral with a ball turning in the socket formed by two clamping jaws, so shaped and pivoted as to maintain a firm grip of the ball, yet so "tensioned" as to let the ball "roll" in the socket when a change in the angle of tilt is desired. Holding pressure exerted on the ball is supplied by a heavy tension spring which actuates the two clamping jaw members.

According to Mr. D. F. Carscadden of the Metro-Vise Company, 246 Stephenson Bldg., Detroit 2, Mich., pressure by the babbitt jaws is sufficient to hold the ball in shift-proof position during normal as-

Industry Endorses EUTECTIC Low Temperature WELDING RODS* and FLUXES

"THE MOST REMARKABLE DEVELOPMENT† SINCE THE INVENTION OF THE WELDING TORCH!"

Robert F. Miller - President of Pottstown Mfg. Co., Pottstown, Pa.

MANUFACTURER OF MACHINE PARTS AND ASSEMBLIES, INCLUDING TUBE BENDING AND WELDED SECTIONS

"We fabricated these aircraft ordnance parts with EutecRods 16 for steel (1300-1600°F.), No. 1800 for ferrous and non-ferrous metals (940-1120°F.), No. 190 for aluminum and alloys (950-1060°F.) and No. 1601 for alloy steel (1020-1250°F.). The use of these Low Temperature Welding Rods reduced our production costs materially. As many as 4000 pieces were produced with a No. 16 rod, and inexperienced girls were expertly welding tough and delicate parts after only a few hours of instruction from our welding specialist George Bauer. Because EUTECTIC Low Temperature Welding Rods can be applied with ease, we maintained a greater operating efficiency among our plant personnel."

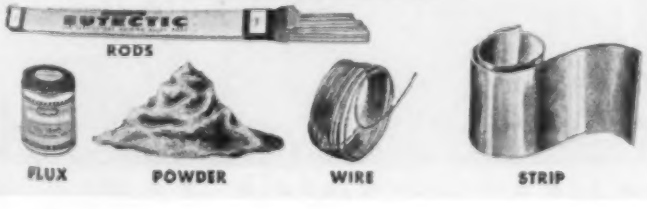
INVESTIGATE EUTECTIC TODAY

In production, EUTECTIC Low Temperature Welding Rods* play a vital role. Because they can be successfully applied by beginners—because they can be used with extremely low heat and produce welds that are more machinable, show less stress and distortion and exhibit consistently high strength—EutecRods and EutecTrodes are a growing factor in major civilian production work and are *rapidly displacing fusion welding and brazing.*

All EUTECTIC Alloys are now available for civilian production. By means of 48 specially developed Rods and Fluxes you can employ the many revolutionary advantages of EUTECTIC Low Temperature Welding. Get the facts today! Call in your local EUTECTIC Field Engineer and learn how EUTECTIC can be made to serve you.

Write for Eutectic's Civilian Production Folder EW-20 Today!

Castolin Eutectic



*Trade Mark Reg. U. S. Pat. Off.

†WHAT IS EUTECTIC?

EUTECTIC Low Temperature Welding Rods are a new type of welding alloys, which—

- **Bond to base metals well below the base metal melting point**
- **Avoid the dangers of stress and distortion characteristic of fusion welding**
- **Form exceedingly strong bonds through surface alloying**

EUTECTIC WELDING ALLOYS COMPANY

40 Worth Street New York 13, N. Y.

Please send me complete facts about EUTECTIC Rods and Fluxes and information on how to purchase a selection of the 9 most important EutecRods for every day use. Dept. JN1

Name.....

Company.....

Address.....

SLOTTED FACE PLATE
QUICKLY TILTED TO ANY ANGLE
SPRING TENSION ADJUSTING SCREW
RELEASE OR LOCK PLATE IN POSITION
BABBITT JAWS
SMOOTH OPERATING BALL AND SOCKET PRINCIPLE
HEAVY TENSION SPRING
VISE OR FIXTURE

sembly operations. However, when the vise or fixture requires to be given a different angle, the ball is instantly responsive to simple hand pressure. There are no fixed graduations, therefore there is unlimited freedom of movement—any angle, any direction. When proper adjustment is made there is no time lost in making tilting adjustments and both hands are left free for other work. By means of a simple adjustment screw, the tension of the spring can be adjusted to the character of the work being performed.

The model S Metro Positioner is supplied in two sizes, full information on which can be obtained by writing the manufacturer direct.

WORLD'S LARGEST ROLL SPOT WELDER

Speeds as high as 300 welds per minute on 0.032-in. aluminum sheets are being obtained at the New Kensington plant of Aluminum Co. of America on this Federal welder. The Westinghouse electronics controls charge as many as 84–120 mfd. capacitors (10,080 mfd.) from 1500 to 3000 volts with a peak demand of 100 kva. on a three-phase system. Each time this charge is "dumped" into the welder transformer, a weld is formed. The electronic controls for the capacitor discharge system assure the right amount of current for consistent welding results whether 0.032-in. sheet or 0.087-in. sheet is being put through the welder (See Fig. 1).

The electronic controls assure consistent welding results on sheet aluminum from 0.032 in. to 0.187 in. thick. The operator's adjustment panel is conveniently mounted next to the roll spot welder. In the center is the main control cabinet for the capacitor-discharge system (see Fig. 2). In it are housed: rectifier, voltage regulating system and part of the capacitor bank. In the extreme right-hand cabinet the balance of the capacitor bank is housed.

BANTAM BULLY HAMMER

A small, powerful pneumatic hammer, delivering some 13,000 blows per minute and operating on less than 2 cu. ft. of air at 80 to 100 psi., will be released for general distribution for the first time this month, according to announcement by the manufacturer, Superior Manufacturing Co., Public Square Building, Cleveland 13, Ohio. A 4-page bulletin describing the hammer in detail is available. Originally designed for special applications, where an exceptionally small tool with plenty of power and long lasting qualities were demanded, the air hammer has heretofore been sold by the manufacturer almost exclusively to war production plants.

Weighing less than 2 lb., the hammer, appropriately named the "Bantam Bully" fits easily in the hand. A pistol grip handle, of dimpled aluminum casting, gives the operator comfortable control of the rapid-firing power of the hammer. The valve control, in pistol trigger position, adds to the ease of control.

Tools for the hammer, of which a wide variety are available, are loaded in a quick, acting, ball-and-channel locking chuck. A quarter-turn of the knurled nose of the chuck locks or releases any of the tools. The "Bantam Bully" hammer has but only one moving part, the piston striking member, which is precision fitted in a finely ground cylinder. Travel of the hammer piston is approximately $^3/_8$ in. and normally operates between 12,000 and 14,000 blows per minute, depending upon the trigger regulation and the air pressure available.

Uses so far discovered for the tool include all kinds of cold chiseling of metals, peening, welding flash stripping, light

scaling, light riveting, forming and finishing, routing of all kinds, paint and rust removal (particularly good on jobs such as steel stacks and walls) star-drilling cement, caulking, template marking, loosening stubborn threaded fastenings by vibration, fender work, wood gouging in pattern making and many special driving, cutting and vibrating jobs in electric motor and small machinery assembly.

MAKING YOUR OWN OXYGEN

A booklet has been issued by Air Products, Incorporated, Manufacturers Road, Chattanooga 5, Tenn., to explain its method of producing oxygen at lower costs. The booklet was prepared to answer the increasing number of requests for information.

PAGE OFFICE

Page Steel and Wire Division of American Chain & Cable Company, Inc., has established a new sales office in the General Motors Building, Detroit, Michigan, in order to improve customer service. E. B. Brant and W. R. Stephens, formerly at the Page plant at Monessen, Pa., will make their headquarters in the Detroit office.

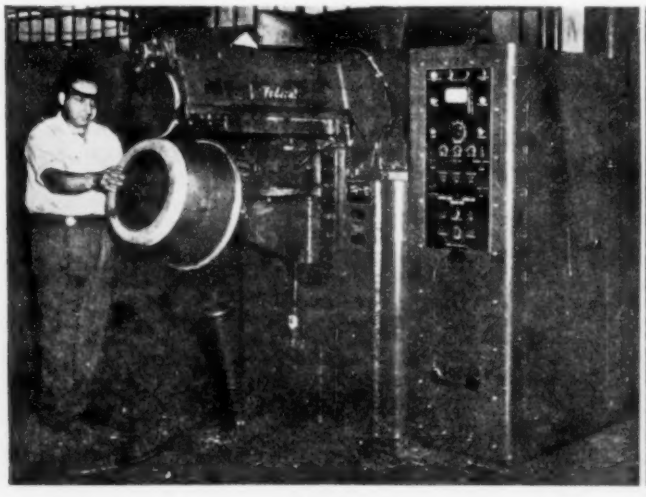


Fig. 1

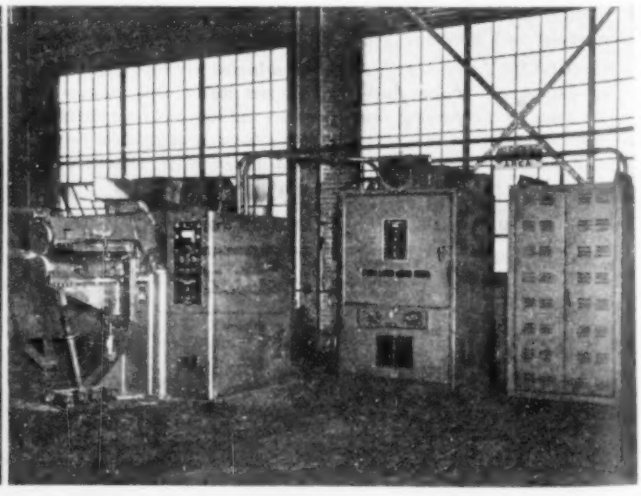


Fig. 2

WHERE WELDS MUST BE RIGHT

Industry Depends on G.E. X-Ray

G-E X-Ray Units are important inspection tools . . . used by leading weld fabricators to insure high quality in their work . . . and x-ray is equally important to leading producers of welding electrodes.

For example, the Hollup Corporation of Chicago employs a 200,000-volt G-E Industrial X-Ray Unit to inspect test welds made with their electrodes. Thus, Hollup insures unvarying quality of its products. Utilizing x-ray to insure top-flight quality of each of the numerous types of electrodes they produce is but one benefit gained by this company.

They also find x-ray an invaluable development tool. All new types of electrodes introduced by Hollup are built to x-ray established standards. From development through production, their G-E X-Ray Unit is constantly employed in proving and improving product fitness.

There's a G-E X-Ray Unit for *your* application. Your request for detailed information will receive prompt attention. Investigate today! Write or wire to General Electric X-Ray Corporation, 175 West Jackson Blvd., Chicago 4, Illinois, Department N-810.

1895 OUR FIFTIETH YEAR OF SERVICE 1945

GENERAL ELECTRIC X-RAY CORPORATION

SECTION ACTIVITIES

COLUMBUS

The Columbus Section has elected the following officers to serve for the coming year.

Chairman, Robert D. Williams, Battelle Memorial Institute.

Vice-Chairman, F. W. Shackleton, Penn Welding Co.

Sec.-Treas., George S. Herren, Seagraves Corp.

INDIANA

The first meeting of the 1945–46 season was held on September 28th at the Lincoln Hotel, Indianapolis. W. M. Woll of the Commonwealth Edison Co., Chicago, talked on "High Frequency, Induction and Dielectric Heating."

MILWAUKEE

The first meeting was held on Sept. 28th in the Ambassador Hotel. Mr. J. A. Gallaher of the Haynes Stellite Co. of Chicago spoke on "The Selection of Hard-Facing Materials and Methods. Mr. Gallaher is author of several excellent articles on this subject which have appeared in the Journal.

A series of five meetings are to be held beginning October 30th and running through November 27th as an educational program. The list of lectures with subjects are as follows:

Oct. 30th—"Welding Processes and Symbols," L. C. Bibber, Carnegie Illinois Steel Corp.

Nov. 6th—"A.W.S. Classification of Electrodes," Dr. Smith, Harnischfeger Corp.

Nov. 13th—"Welding Codes and Specifications," Charles Scudder, A. O. Smith Corp.

Nov. 20th—"Safety Factors in Welding," F. R. Mallette, National Safety Council.

Nov. 27th—Welding films consisting of: A. "Prevention and Control of Distortion in Arc Welding." B. "The Inside of Atomic Hydrogen Welding," by the General Electric Co. C. "New Horizons in Welding," by the Harnischfeger Corp.

NEW YORK

The regular monthly technical meeting of the New York Section was held on Tuesday, September 11th, at the Engineering Societies Building. Robert E. Bedworth, Western Electric and Manufacturing Co., N. Y. C., presided as chairman for the evening.

The speaker for this meeting was Charles H. Jennings, Section Engineer of the Welding Sections, Westinghouse Electric and Manufacturing Co., East Pittsburgh, Pa. Mr. Jennings spoke on the subject "Distortion in Welding." He gave much of the latest factual data and explained many of the theories on distortion that have been accumulated in the past few years. Mr. Jennings' talk gave the New York Section a very interesting and informative start for the first meeting of the new season. Refreshments and an informal discussion followed the technical meeting.

NORTHWESTERN PENNSYLVANIA

A new Section under the above name has been formed and the following are the officers elected as of August 10, 1945.

Chairman, C. W. Lytton, The Lincoln Electric Co.; *Vice-Chairman*, W. H. Cochran, General Electric Co.; *Secretary-Treasurer*, Wilfred R. Boyd, Boyd Welding Co.

NORTHWEST

Starting the Section's ninth year was a meeting held on September 6th. T. B. Jefferson, Editor of *The Welding Engineer*, spoke on "Postwar Welding Possibilities." Mr. Jefferson outlined the part welding has played in the war effort, as well as some of the problems that will face welding in the postwar period.

PASCAGOULA

Opening of the fall season took place with a dinner meeting held at the Pascagoula Country Club on October 2nd. The principal speaker was W. R. Gues, Sr., Executive Vice-President of the Ingalls Shipbuilding Corp., who spoke on "Ingalls Postwar Program." Milton Forman, Welding Engineer, also with Ingalls, delivered a paper on "Fundamentals in All-Welded Ship Construction."

PHILADELPHIA

The following committees have been appointed for the fiscal year:

Membership: George R. Johnson, M. W. Brewster, Fred Judelsohn. *Education:* H. W. Pierce, R. D. Thomas, Jr., A. R. Anderson. *Program:* H. B. Seydel, E. E. Goehringer, J. D. Bert. *Discussion Groups:* E. R. McClung, O. C. Frederick, A. J. Raymo, W. E. Hendricks. *Entertainment:* O. J. Pearre, A. B. Gordon, B. B. Ross. *Building:* W. F. Carson, R. E. Seiffert. *Representatives to Affiliated Technical Societies Council of Philadelphia:* H. W. Pierce, G. R. Johnson.

Professor Gilbert E. Doan of the Department of Metallurgical Engineering, Lehigh University, spoke on the subject "Weldability" at the Section's September meeting. Progress made during the recent war period has greatly expanded the meaning of the term Weldability and a lively discussion period led by Prof. Doan's associate, Dr. Robert D. Stout, followed the main talk.

The Section presented resolutions of thanks to W. W. Barnes and R. D. Thomas for their untiring efforts in behalf of the Section since its origin in 1920.

ROCHESTER

The following arrangements for the season have been made by the Rochester Section.

A change in the size and contents of the meeting notices. This will permit more items of interest about the speakers, members and advertisers.

By popular request from all the members, each meeting will have a 15-minute discussion on welding applications by a local speaker or speakers.

By the same popular request, an interesting movie will also be shown at each assembly.

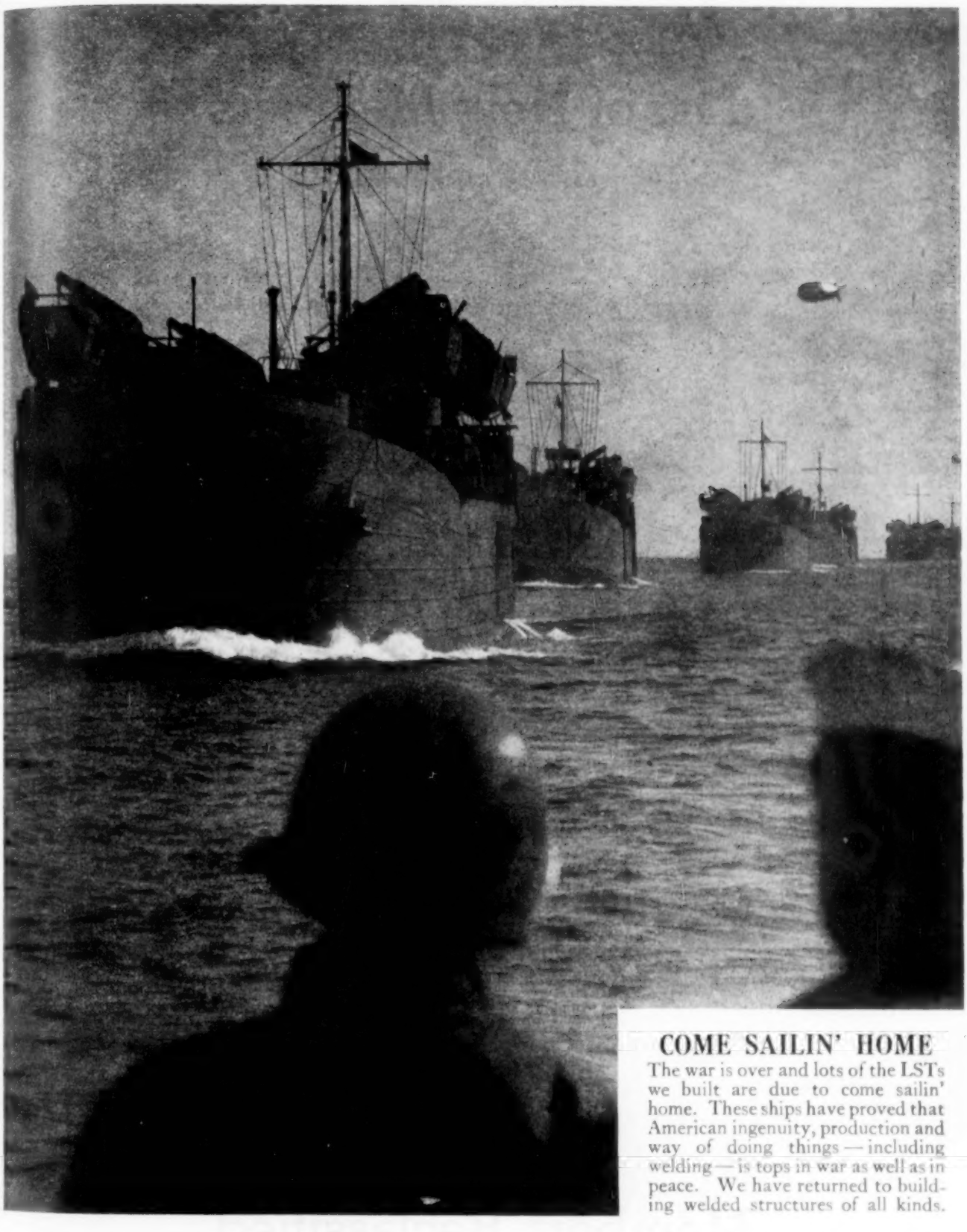
At the October 4th meeting, W. S. Pelton, General Electric Co., was guest speaker. His subject was "Brazing on the Production Line." The 15-minute discussion period was conducted by Robert Raudebaugh of the University of Rochester, and Larry Smith of The Lincoln Electric Co., on the subject of Weldability. The Lincoln Electric film entitled "Prevention and Control of Distortion in Arc Welding" was also presented.

The guest speaker for the November 1st meeting will be T. B. Jefferson, Editor of *The Welding Engineer*. The 15-minute discussion period will be conducted by Robert Cattanach of the American Laundry Machine Co.

The December 6th meeting will have Bela Ronay of the Naval Experiment Station, Annapolis, Md., as guest speaker.

SYRACUSE

The September meeting was held on the 12th. William Conley, Consulting Engineer, The Lincoln Electric Co., spoke on "Stresses and Strains—Polarized Light." A motion picture, "Prevention and Control of Distortion in Arc Welding," was also shown.



COME SAILIN' HOME

The war is over and lots of the LSTs we built are due to come sailin' home. These ships have proved that American ingenuity, production and way of doing things — including welding — is tops in war as well as in peace. We have returned to building welded structures of all kinds.

CHICAGO BRIDGE & IRON COMPANY

Chicago 4 ..... 2455 McCormick Bldg.	Birmingham 1 ..... 1907 North 50th Street	Washington 4 ..... 703 Atlantic Bldg.
New York 6 ..... 3398—165 Broadway Bldg.	Tulsa 3 ..... 1654 Hunt Bldg.	Philadelphia 3 ..... 1668-1700 Walnut Street
Cleveland 15 ..... 2282 Guildhall Bldg.	Atlanta 3 ..... Healey Bldg.	Los Angeles 14 ..... 1471 Wm. Fox Bldg.
Havana ..... Edificio Abreu 402	Houston 1 ..... 5621 Clinton Drive	San Francisco 11 1297-22 Battery Street Bldg.

Fabricating plants in CHICAGO, BIRMINGHAM; and GREENVILLE, PA.

List of New Members

August 1 to August 31, 1945

CANADA

Becker, Paul (B), 129 Norman St., Sornia Ontario, Canada.

CHICAGO

Graham, Robert N. (C), A. O. Smith Corp., 310 S. Michigan, Chicago 4, Ill.

CINCINNATI

Schnelle, Ernst G., Jr. (C), 4 E. Benson St., Reading 15, Ohio.
Schnella, Wm. C. (C), 1932 Fairfax Ave., Cincinnati 7, Ohio.
Shepard, Kenneth Ray (C), 4166 Janward Dr., Cincinnati 11, Ohio.

CLEVELAND

Jackson, Ben F., Sr. (C), R. D. 2, New Waterford, Ohio.
Johnson, Minot M. (B), 402 Switland Bldg., Cleveland, Ohio.
Mergel, Henry (C), 7004 Hague Ave., Cleveland, Ohio.
Pestrak, Walter (B), Progressive Welder Co., 1015 Mohoning Bank Bldg., Youngstown, Ohio.

DETROIT

Appleby, James A. (C), 4237 Commonwealth, Detroit, Mich.
Stickney, W. R. (B), Canadian Vickers, Ltd., P. O. Box 550, Pl. Darmer Sta., Montreal, Quebec, Canada.

HAWAII

Cunha, Allen H. (C), Hawaiian Gas Prods., P. O. Box 2454, Honolulu 4, T. H.

LOS ANGELES

Allen, Orville C. (C), 1063 Los Palos St., Los Angeles 23, Calif.
Harper, Andrew O. (C), 1246 E. 91st St., Los Angeles 2, Calif.
Morris, Richard F. (C), 5017 W. 141st St., Hawthorne, Calif.

MAHONING VALLEY

Reinhardt, G. A. (B), The Youngstown Sheet & Tube Co., Youngstown 1, Ohio.

MARYLAND

Luckert, Milton C. (C), Koppers Co., B. H. Div., 200 Scott St., Baltimore 27, Md.
Wirth, Eugene H. (C), Koppers Co. Bartlett-Hayward Co., 200 Scott St., Baltimore, Md.

MILWAUKEE

Hart, W. H. (C), 735 N. Water St., Milwaukee 2, Wis.
Piekarski, Leon J. (C), 913 N. 27th St., Apt. 3, Milwaukee 8, Wis.
Van Dyke, Clarence A. (C), 2639 N. 37th St., Milwaukee 10, Wis.

NEW JERSEY

Chabot, Joseph (C), 1 Chabot Lane, E. Paterson, N. J.
Kneiper, James E. (C), 67 Chestnut Ave., Bound Brook, N. J.
Leigh, Gilbert M. (B), Metal & Thermit Corp., Research Lab., Box 255, Rahway, N. J.

NEW YORK

Dornheim, G. A. (B), Buensod-Stacey, Inc., 60 E. 42nd St., New York 17, N. Y.
Murray, William W., Jr. (B), Almirall & Co., Inc., 53 Park Pl., New York 7, N. Y.
Truxall, John W. (C), 70 Prospect Park West Brooklyn, N. Y.

NORTHWEST

Shannon, Jerry V. (C), 5807 Tacony St., Duluth 7, Minn.

PHILADELPHIA

Colinet, Rene D. (C), Industrial Research Lab., 421 Memphis St., Philadelphia 25, Pa.

PITTSBURGH

Fishter, Nicholas C. (B), 496 Dorothy Ave., Johnstown, Pa.
Kolm, Roger E. (B), Dravo Corp., Neville Island, Pittsburgh 25, Pa.

PUGET SOUND

Haggard, James E. (C), P. O. Box 2454, Sheridan Pk., Bremerton, Wash.

ST. LOUIS

Cooper, Lloyd (C), Air Reduction Sales Co., 630 S. Second St., St. Louis, Mo.

SAN FRANCISCO

Eklund, Cecil S. (B), 1051 Sunset Blvd., Hayward, Calif.
Hovland, Harold (B), Industrial X-ray Engineers, 420 Market St., San Francisco, Calif.
Matto, Wm. V. (B), 1946—36th Ave., Oakland 1, Calif.
Openshaw, Bernard R. (B), 79 NCB, F.P.O., San Francisco, Calif.
Van Matr, Virgil (B), 9367 Bernhardt Dr., Oakland, Calif.

SOUTH TEXAS

Harris, Henry C. (B), Brown Shipbldg. Co., Inc., P. O. Box 2634, Houston 1, Tex.
Turner, Joe Ruel (B), P. O. Box 2634, Houston 1, Tex.

TACOMA

Gunnette, Elmer E. (B), 3615 N. 22nd St., Tacoma 7, Wash.
Jensen, Norman L. (C), 601 Rochester, Tacoma 6, Wash.
Scoggin, Thos. M. (C), 2715 S. Tacoma Way, Tacoma 3, Wash.

WESTERN MASS.

Moreland, Benjamin W. (B), Worthington Pump & Machy. Co., Holyoke, Mass.

NOT IN SECTIONS

Beck, Arthur J. (B), Messrs. Hume Steel Ltd., P. O. Box 204, Germiston, Transvaal, S. Africa.
Cross, J. H. (C), 2915 Oakwood St., Erie, Pa.
Donnelly, Wm. W. (C), Box 547, Auburn, Wash.
Fernstrom, Gostil Bertil (B), 7 Lillvagen, Norrkoeping, Sweden.
Lagrange, D. (B), 101A Avenue du Prince D'Orange, Uccle, Bruselles, Belgium.
Mac Kenzie, J. B. (C), The Standard Stoker Co., Inc., Erie, Pa.
Miskoe, Wm. I. (C), The Lincoln Elec. Co., (Aust.) Pty. Ltd., 109 Euston Rd., Alexandria, N. S. W., Australia.
Oless, Philip J. (C), The Standard Stoker Co., Inc., Erie, Pa.
Swinton, Alexander G. (B), P. O. Box 31, William St., Sydney, Australia.
Willard, Donald B. (C), Box 35, Derrick City, Pa.

Members Reclassified

During Month of August

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Stahl, H. Hugo (from C to B), 35 Hutchinson Rd., Arlington 74, Mass.

CANADA

Voyer, Joseph Jean Paul (from D to C), 966 Gilford, Montreal, Quebec 34, Canada.

COLUMBUS

Schulz, Earl (from D to C), 503 W. 7th Ave., Columbus 1, Ohio.

How the New Murex Type U Eased Jonesy's Supervisory Duties

Jonesy, our arc welding super, looked at this new job that came in and emitted a stricken groan. Being his secretary, I acted sympathetic.

"Miss Clark," he complained, "I am unhappy. Look at this weird assembly, of which they expect me to do ninety before the week is out. Vertical fillets here, downhand fillets there, and darned if there isn't even some overhead welding—wish we had one rod that would do the whole job. Besides looking after my routine work, I will be all over this place like a blue-bottle fly, keeping the boys straight on which rod to use and where. I *am* unhappy."

"And deservedly so," I said tartly, "for not keeping up with events in the arc welding world. Metal & Thermit has just come out with a new E-6013 rod that makes *any* type of weld in *any* position with *any* current. They call it Type U, meaning Universal. Its arc is penetrating and easily handled. Welds are smooth and unusually sound. Slag is easy to remove. The rod is ideal on complicated jobs where you want high quality without a lot of supervision. (P.S. I'm so glib about it because I've just read the M & T bulletin!) We use several of Metal & Thermit's Murex electrodes already: want to try their new Type U?"

We tried their new Type U, and it did everything I had read it would do. Jonesy was jubilant. Better try it yourself: it saves lots of time and supervisory bother, besides doing a fine all-around job.

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DETROIT

Hoss, J. P. (from C to B), Weldit Acetylene Co., 638 Bagley Ave., Detroit 26, Mich.

INDIANA

Grubbs, Paul F. (from C to B), P. R. Mallory Co., 3029 E. Washington St., Indianapolis 6, Ind.

LOS ANGELES

Baker, Richard I. (from D to C), 222 E. 84th Pl., Los Angeles 3, Calif.

LOUISVILLE

Schiller, Clarence E. (from D to C), 503 Crestview St., Jeffersonville, Ind.
Schlatter, Henry J. (from D to C), 1922 Payne St., Louisville 6, Ky.

MAHONING VALLEY

Jones, Ralph M. (from C to B), 444 Falls Ave., Youngstown, Ohio.

MILWAUKEE

Monsler, Melvin O. (from C to B), 1517 S. 60th St., West Allis 14, Wis.

NEW JERSEY

Kelly, James P. (from D to C), 109 Orient Ave., Jersey City 5, N. J.

PASCAGOULA

Dick, Charles M., Jr. (from C to B), 1309 E. Tyler Ave., Pascagoula, Miss.

PHILADELPHIA

Holzbauer, Arthur A. (from C to B), Middletown & Fox Rds., R. D. 2, Media, Pa.

PUGET SOUND

Darr, Eugene E. (from C to B), K-41 Cedar River Park, Renton, Wash.

SAN FRANCISCO

Rhoades, Harold E. (from C to B), c/o National Cylinder Gas Co., 326 Howard St., San Francisco, Calif.

SOUTH TEXAS

Dye, Gil V. (from C to B), Dye Welding Supply Co., 4515 Fannin, Houston 4, Tex.

WESTERN NEW YORK

Bugenhagen, Lorenzo (from D to C), 199 Midland Ave., Kenmore 17, N. Y.

NOT IN SECTION

Shaffner, George W. (from C to B), 1215 Corregidor Circle, Evansville 14, Ind.

Employment Service Bulletin

POSITIONS VACANT

Wanted: Local representatives who are now calling on wholesalers in the hardware and welding fields to handle our complete line of safety equipment. Excellent opportunity. Write for full details. American Industrial Safety Equipment Co., 398 Bridge St., Brooklyn, N. Y.

V-176. Electrode Formulator. Large manufacturer of welding electrodes needs man with engineering background to assist in the development of new electrodes. Some experience in formulation desirable, but not necessary. Write details of education and experience. Our organization has been informed of this insertion.

SERVICES AVAILABLE

A-503. Supervisor desires position. For the past four and one half years employed by the New York Navy Yard as Supervisor in Charge of the Welding Inspection Department for new construction and salvage work. Prior experience: Twelve years mechanical repair and maintenance of internal combustion engines; ten years machine shop experience. Also a licensed structural steel welder.

A-504. Graduate Electrical Engineer with ten years experience in the field of welding engineering covering the design of power systems for supplying electric arc and resistance welding machines; design of joints for electric arc, resistance welding, submerged arc, automatic arc, and atomic hydrogen welding; and development of welding procedure and sequence. Will accept a welding sales and service position or an engineering supervisory position in a manufacturing concern with either a resistance welding or arc welding company. New York, New Jersey or Pennsylvania area.

WELDED STOOLS

Steel stool, available in five heights and 40 models, which have a diversity of industrial and commercial uses, are now being marketed by Lyon Metal Products, Inc., Aurora, Ill., it is announced.

The 80 models, the Company asserts, which have been designed from a physiological standpoint to meet every posture need in busy plants, aid materially in increasing employe efficiency by reducing fatigue.

The 26-inch stool pictured here, No. 1226, equipped with an adjustable back and pressed wood seat (over steel) and steel feet, is priced at $2.40. The back support may be attached to all models.

This stool has innumerable features, including all-welded, non-breakable construction; unusually large, comfortable 14-inch wide seat, with rounded corners, strong channel brace which provides a comfortable foot rest located at a uniform distance below the seat from all heights; steel glide type feet and long life pressed wood seat applied over steel for strength.

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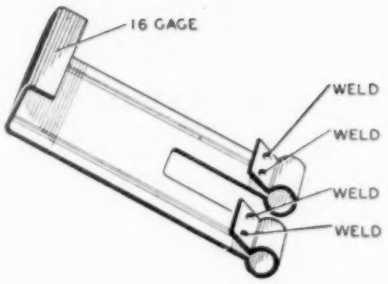

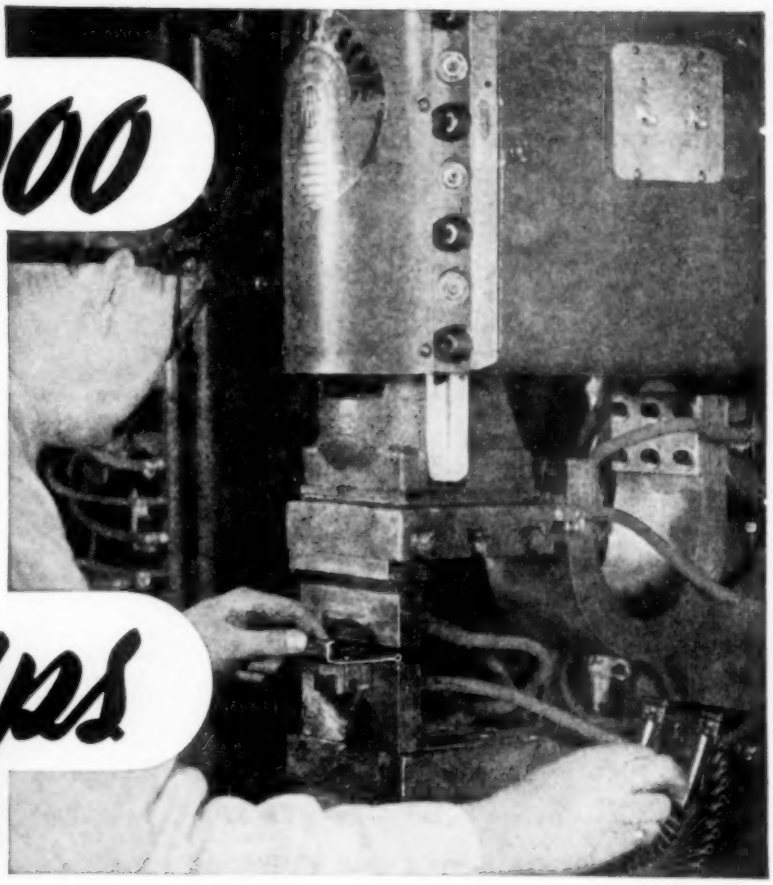

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Four small projections are stamped into the metal near the hinge eyes in the forming operation. To secure the eyes, the hasp is merely laid on the lower die of the welder. The upper die comes down, current comes on automatically, and welds the eyes closed at the projections.

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CHAIRMAN—H. O. KLINKE, Air Reduction Sales Co., 181 Pacific Ave., Jersey City, N. J.
SECRETARY—G. SYKES, The Linde Air Products Co., 30 E. 42nd St., New York 17, N. Y.

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SECRETARY—G. M. RHOADES, JR., Industrial Engrg. Div., General Electric Co., Schenectady, N. Y.

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SECRETARY—GEORGE R. LANGZETTEL, 22 Thomas St., Portland, Me.

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SECRETARY—F. W. TAFT, Taft Welding Equip. Co., 3171 Main St., Springfield, Mass.

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SECRETARY—CHARLES FREEMAN, The Lincoln Elect. Co., 807 Iroquois Bldg., Buffalo, N. Y.

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SECRETARY—JULIUS NAAB, Ingersoll-Rand Co., Phillipsburg, N. J.

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SECRETARY—R. FITZGERALD, Consolidated Gas Elect. Light & Power Co., Westport, Sta., Kloman St. Baltimore 30, Md.

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SECRETARY—A. PILTEN, 1445 Otis Place, N. W., Washington 10, D. C.

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BIRMINGHAM — 1st Thurs.
CHAIRMAN—W. B. BROWNING, The Linde Air Products, 1001-13 S. 22nd St., Birmingham, Ala.
SECRETARY—W. L. POOLE, Air Reduction Sales Co., 2825 N. 29th Ave., Birmingham, Ala.

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CHAIRMAN—REYNOLD ALONZO, Rt. 3, Box 24, Stanton Rd., Mobile, Ala.
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SECRETARY—T. B. JEFFERSON, The Welding Engineer, 506 S. Wabash Ave., Chicago, Ill.

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#6—MID-SOUTHERN

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SECRETARY—L. L. STEWART, Welders Supply Co., Box 653, Oklahoma City, Okla.

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SECRETARY—A. E. WISLER, Hughes Tool Co., 300 Hughes St., Houston, Tex.

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SECRETARY—JAMES B. DAVIS, Tulsa Testing Labs., Tulsa, Okla.

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- ★ THREADS CARRY NO CURRENT
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ELECTRODE SLOT
holds electrode firmly at proper angle

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protects insulation and resists weld spatter

PUSH-UP ROD
A slight twist of the hand tightens electrode, gives a firm "cushion grip." Threads do not carry current

HANDLE
is light in weight and comfortable to the grip. A twist of the handle releases electrode

SOLDERED CABLE CONNECTION
assures good electrical contact, resulting in a cool handle

HERE is an electrode holder *designed from the operator's point of view.* It is light in weight, amazingly cool in operation, and provides a new degree of safety. The head of the holder is completely enclosed in a sheath of aluminum armor to protect the insulation and to eliminate danger of accidental contact with the welding circuit. Spatter won't stick to this aluminum sheath—the holder stays clean, lasts longer.

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SECRETARY—ALAN G. SLIPPER, Hawaiian Gas Products Co., P. O. Box 2454, Honolulu, T. H.

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SECRETARY—DONALD B. TOWLER, 1730-B Kalani St., Honolulu, T. H.

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SECRETARY—PAUL KULLBERG, Industrial Specialties Co., 940 S. E. 7th Ave., Portland 14, Ore.

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